

AD-A154 343

**NASHUA RIVER BASIN
HOLDEN, MASSACHUSETTS**

**KENDALL RESERVOIR DAM
MA 00622**

**PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM**

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**DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154**

OCTOBER 1978

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The dam is an earthfill dam located at the northern end of Kendall Reservoir. The dam is about 1120 ft. long and 39 ft. high. The major problems are the deteriorating concrete on the spillway. Generally the dam is considered to be in good condition. It has been classified as high in the hazard category. It is recommended that the City of Worcester employ a qualified engineer to investigate the seepage at the toe of the dam.		

KENDALL RESERVOIR DAM

MA 00622

NASHUA RIVER BASIN
HOLDEN, MASSACHUSETTS

PHASE I - INSPECTION REPORT
NATIONAL DAM INSPECTION
PROGRAM

NATIONAL DAM INSPECTION
PROGRAM
PHASE I INSPECTION REPORT
BRIEF ASSESSMENT

Identification No.: MA00622

Name of Dam: Kendall Reservoir

Town: Holden

County and State: Worcester County, Massachusetts

Stream: Kendall Brook - Tributary of Asnebumskit
Brook

Date of Inspection: September 13, 1978

Kendall Reservoir Dam is an earthfill dam located at the northern end of Kendall Reservoir. An earthfill dike is located at the southern end of the reservoir. The dam and dike were both constructed around 1911 for a water supply reservoir by the City of Worcester. The dam is about 1,120 feet long and a maximum of 39 feet high. The dike is about 210 feet long and 7 feet high. The spillway is a rectangular concrete channel through the dam. The weir which is 35 feet long, has flashboards 18 inches high. There is an outlet conduit beneath the embankment that terminates in a concrete headwall at the downstream toe. Discharge from this conduit flows north to Eagle Lake. There is also a gate house located on the dike. The outlet conduit from the gate house is regulated by the City of Worcester to provide water to the distribution reservoirs. Flow is controlled by slide gates at two inlets under the gate house. The discharge conduit is a 30-inch cast-iron pipe which extends 1,000 feet south, and discharges at a concrete distribution basin.

Additional structures were designed to allow water to flow from Quinapoxet Reservoir and Pine Hill Reservoir, north and west of Kendall Reservoir. The purpose was to maintain a high water level in Kendall and the lower reservoirs (Holden No. 1 and No. 2).

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The dam and dike were neither designed nor constructed according to current approved procedures. Based on the visual inspection, the limited engineering data, and inadequate maintenance of the appurtenances, certain conditions at the dam must be corrected to assure the continued performance of the structures. Generally, the dam and dike are considered to be in good condition. Because of the potential danger to lives and property downstream of Eagle Lake, the dam has been placed in the "high" hazard category according to Corps of Engineers guidelines for hazard potential.

The major problems are the deteriorating concrete on the spillway, particularly on the side walls; the slight seepage in the vicinity of the outlet at the toe of the dam; and the accumulation of soil and debris burying the outlet at the headwall.

Hydraulic analyses indicate that the spillway (without flashboards) can discharge a flow of 2,022 cubic feet per second (cfs) at elevation (El) 820.0, which is approximately the top of the dam.

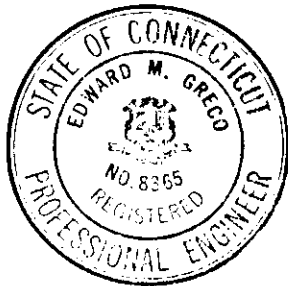
An outflow test flood of 1,700 cfs (the probable maximum flood) would raise the reservoir level to a maximum El 819.2, and would not overtop the dam.

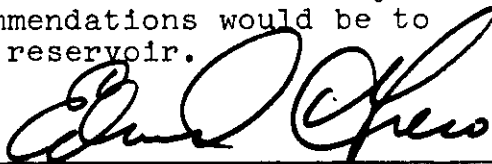
It is recommended that the City of Worcester employ a qualified consultant to investigate the seepage at the toe of the dam. It is also recommended that the Owner repair the concrete on the spillway, clear the debris from the outlet, and fill in the animal burrows on the slopes. The Owner should continue the program of maintenance inspections.

Repair of the spillway and outlet at the dam should be undertaken by the Owner within a year of receipt of this Phase I Inspection Report. The

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remaining work should be implemented within two years.
An alternative to these recommendations would be to
lower the water level in the reservoir.



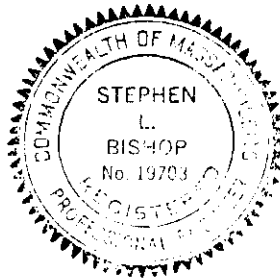

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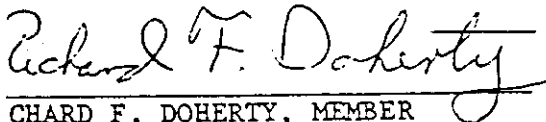

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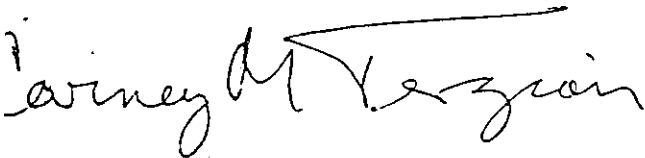


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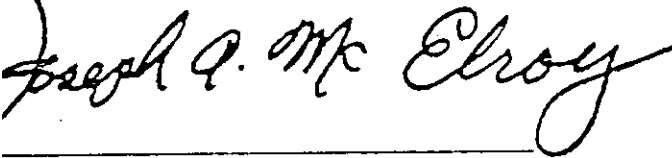
is Phase I Inspection Report on Kendall Reservoir Dam
s been reviewed by the undersigned Review Board members. In our
inion, the reported findings, conclusions, and recommendations are
nsistent with the Recommended Guidelines for Safety Inspection of
ms, and with good engineering judgment and practice, and is hereby
bmitted for approval.



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PREFACE

This report is prepared under guidance contained in Recommended Guidelines for Safety Inspection of Dams, for a Phase I Investigation. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrology and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general conditions and the downstream damage potential.

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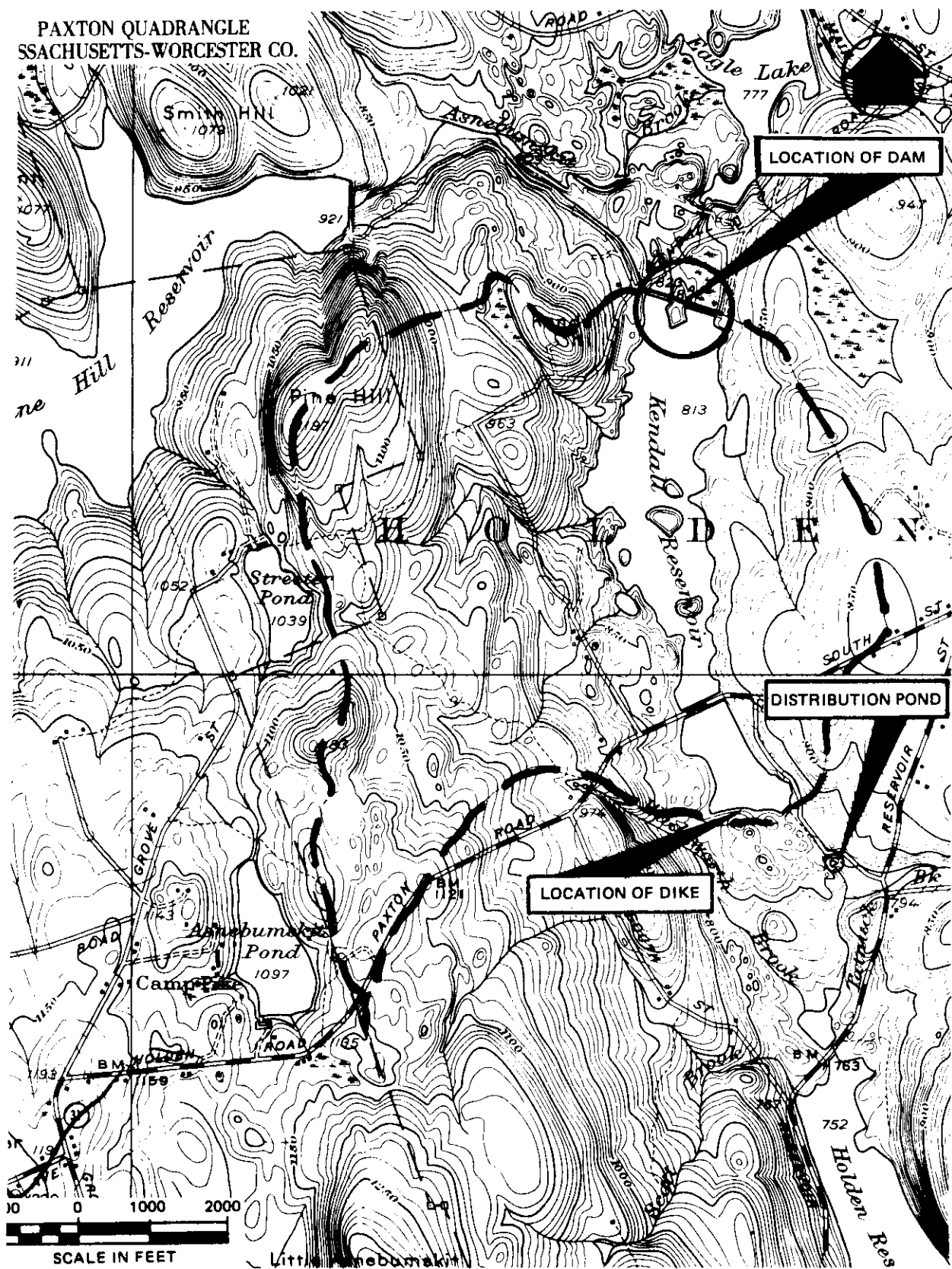
**OVERVIEW
KENDALL RESERVOIR
HOLDEN, MASSACHUSETTS**



UPSTREAM FACE OF DAM, AND SPILLWAY

**Location and Direction of Photographs
Shown on Figure in Appendix B**

PAXTON QUADRANGLE
MASSACHUSETTS-WORCESTER CO.



LOCATION MAP - KENDALL RESERVOIR DAM

NATIONAL DAM INSPECTION
PROGRAM
PHASE I INSPECTION REPORT

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SECTION 1

PROJECT INFORMATION

1.1 General

- a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Metcalf & Eddy, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued to Metcalf & Eddy, Inc. under a letter of July 28, 1978, from Ralph T. Garver, Colonel, Corps of Engineers. Contract No. DACW 33-78-V-0306 has been assigned by the Corps of Engineers for this work.
- b. Purpose
 - (1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.
 - (2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.
 - (3) Update, verify and complete the National Inventory of Dams.

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1.2 Description of Project

- a. Location. Kendall Reservoir Dam is located on Kendall Brook, a tributary of Asnebumskit Brook, in the Town of Holden, Worcester County, Massachusetts (see Location Map).
- b. Description of Dam and Appurtenances. There are two impoundment structures on Kendall Reservoir: an earthfill dam at the northern end, and an earthfill dike at the southern end. Route 31 (South Road) crosses the reservoir on an embankment near the southern end (see Location Map). The main dam is a maximum 39 feet high and is divided into two sections by a ridge of natural ground. The east section is about 740 feet long and the west section about 380 feet long. The flat, grass-covered crest is about 25 feet wide. The average elevation of the crest varies only slightly from 819.9 at the upstream side, to 820.7 at the downstream side. The upstream face of the dam is protected with riprap, and the slope is estimated at 2:1 (horizontal: vertical). The downstream face, which is covered with grass, slopes at about 2 to 2.5:1. The toe at the downstream slope is generally at the tree line.

There are three manholes on the crest of the dam: two, 100 feet, and one, 400 feet west of the right abutment. The first two manholes provide access to a surge relief chamber and two valves. The line is a 36-inch riveted steel force main through which water is pumped from Quinapoxet Reservoir to Kendall Reservoir. Two 11 mgd (million gallons per day) pumps at Quinapoxet Reservoir pump the water through the line. The outlet for the pipe is submerged about 10 feet below the elevation of the crest of the spillway. A blow-off pipe for this line can be seen protruding from the upstream face of the dam, overhanging the reservoir.

The third manhole, at 400 feet west of the east abutment, provides access to the low-level outlet. This manhole was opened, and

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found to be a dry, concrete chamber. The gate valve was not visible from the ground surface.

There is a concrete headwall at the outlet of the conduit, in the woods beyond the downstream toe of the dam. This headwall is mostly buried under soil and debris, and the pipe is not visible.

The concrete rectangular channel spillway is located about 350 feet east of the west abutment. It is a flat, broad-crested weir constructed with a concrete slab and concrete side walls.

The crest of the spillway, which is 35 feet long, is at El 813.0 (benchmark elevation estimated from a U.S.G.S. topographic map). Flashboards on the crest of the weir are 1.5 inches thick and a total of 18 inches high. The flashboards are supported by seven square iron pins. There is also a concrete arched footbridge spanning the spillway. The spillway side walls are 8 feet high at the maximum. The concrete downstream channel is 35 feet wide, 130 feet long, and slopes at about 7:1 (estimated from Figure B-1). The side walls are also concrete, and about 3 feet high.

The Asnebumskit Canal (see Figure B-2) is an open concrete channel that conveys water from Pine Hill Reservoir to Kendall Reservoir. The discharge spillway for the canal is located upstream of the west abutment of the dam. Water flows over the 120-foot long concrete weir and down a gently dipping (3:1) field-stone cascade. The crest of this weir is 3 feet higher than the crest of the spillway at the dam. Flow into the canal and therefore into Kendall Reservoir is controlled by a dam and headworks situated about 1/2-mile northwest on Asnebumskit Brook.

The dike at the southern end of the reservoir is 210 feet long and a maximum of 7 feet high (see Figure B-3, Plan of Dike). The crest of the dike is generally 27 feet wide, except in the area of the gate house. The elevation of the grass-covered crest varies from 820.8 to

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823.0. The upstream slope is approximately 3:1 and covered with riprap. The downstream face, which slopes at 2:1, is covered with grass. There is also a concrete staircase on downstream face that is used as a walkway to the gate house.

The gate house is located on an earth berm which extends into the reservoir from about the midpoint of the dike. It is a single-story concrete superstructure on a concrete foundation. The intake structure is rectangular and extends below the floor of the gate house. Two gates allow water to enter a buried 30-inch cast-iron outlet pipe which leads to the distribution basin about 1,000 feet downstream.

- c. Size Classification. Kendall Reservoir Dam is classified in the "intermediate" category since it has a maximum height of 39 feet and a maximum storage capacity of 3,915 acre-feet.
- d. Hazard Classification. Kendall Reservoir is situated in an undeveloped rural area northwest of the City of Worcester. Failure of the dike would result in minor damage to woodland before the flood was channeled into Tatnuck Brook and Holden Reservoir No. 1. However, if the dam failed, the resulting flood water would be discharged to Eagle Lake, about 1/4-mile downstream. Flood water from Kendall Reservoir would raise the level in Eagle Lake, resulting in flooding in the Main Street and High Street areas north of Eagle Lake, and considerable damage to property, and possibly loss of life. For this reason, the dam has been placed in the "high" hazard category. This hazard would be compounded if the flooding resulted in failure of the Eagle Lake dam as well.
- e. Ownership. The reservoir, dam, and dike are owned by the Department of Public Works Operations-Water, City of Worcester, 20 East Worcester Street, Worcester, Massachusetts and are a significant element of the water supply system. Mr. Kenneth Starbard, Supervisor of Water Supply (telephone 617-829-4811), granted

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permission to enter the property and inspect the dam.

- f. Operator. The Supervisor of Water Supply and his staff operate the outlets at the dam as well as pumping stations appurtenant to the system.
- g. Purpose of Dam. The purpose of the dam is to provide storage for the City of Worcester water supply. There are four other integrated reservoirs in the area: Quinapoxet to the north, Pine Hill to the west, and Holden Reservoirs No. 1 and No. 2 to the south.
- h. Design and Construction History. The only plan available for this dam is dated 1905. However, the dam was presumably constructed sometime after 1911, which is when the design was approved by the Worcester County Commissioners. The Asnebumskit Canal, from Pine Hill Reservoir, was apparently built at about the same time. The force main from Quinapoxet Reservoir was not in operation until 1931. Generally the dam has been maintained in good condition since the time of construction. Slight seepage through the embankment of the dam has been noted since the earliest inspection reports (1928). An inspection report dated 1965 cited the deterioration of the concrete spillway. There is no record of subsequent repairs to the concrete. In fact, the inspection reports for both 1965 and 1973 have descriptions similar to the present condition of the spillway. According to the Supervisor of Water Supply, the only previous work in the area pertained to the maintenance of the embankment and grounds.
- i. Normal Operational Procedures. The normal operating procedure at this dam, and at the other dams in the area, is to attain maximum storage in the reservoir, without any waste (overflow) out of the watershed via the spillway. For this reason the flashboards at the spillway remain in place all year round. In addition to direct surface drainage, Kendall Reservoir receives flow from both Quinapoxet and Pine Hill Reservoirs. Discharge from the reservoir is through the

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outlets at the dike, and eventually into distribution reservoirs (Holden Reservoirs No. 1 and No. 2). These outlets remain open as required to maintain the water level in Holden Reservoir No. 2.

1.3 Pertinent Data

- a. Drainage Area. The direct drainage area to Kendall Reservoir is approximately 1,209 acres (1.89 square miles). It consists of hilly woodland areas with limited residential development on South Road (Route 31). Storage at the reservoir is increased by pumping from Quinapoxet Reservoir (maximum rate 22 mgd) and discharge from Pine Hill through the Asnebum-skit C_{nal}.
- b. Discharge at the Dam Site. Normal discharge from the reservoir occurs over the spillway at the dam, to the tributary stream leading to Eagle Lake, about 1/4 mile downstream. Water for the water supply system is discharged through the gates at the dike. Water flows across the drainage divide in a buried 30-inch cast-iron pipe to an open distribution pool about 1,000 feet south of the dike. From there the flow travels in a natural stream channel (Tatnuck Brook) to Holden Reservoir No. 1.

Hydraulic analyses indicate that the spillway can discharge 2,022 cfs at about El 820.0, which is approximately the top of the dam. An outflow test flood of 1,700 cfs (the probable maximum flood) will not overtop the dam.

The dam was not overtopped in the 1938 or 1955 floods.

- c. Elevation (feet above Mean Sea Level (MSL)). A benchmark was established on the crest of the spillway at El 813.0 which was estimated from a U_ S. Geological Survey topographic map.

(1) Top dam: Main Dam: 819.7 to 821.0
Dike: 820.3 to 823.0

(2) Test flood pool: 819.2
KENDALL RESERVOIR DAM

- (3) Design surcharge (original design):
Unknown
- (4) Full flood control pool: Not applicable
(N/A)
- (5) Recreation pool: N/A
- (6) Spillway crest: 813.0
- (7) Upstream portal invert diversion tunnel:
N/A
- (8) Stream bed at dam (outlet channel):
782.0
- (9) Maximum tailwater: None

d. Reservoir

- (1) Length of maximum pool: 7,200 feet
- (2) Length of recreation pool: N/A
- (3) Length of flood control pool: N/A

e. Storage (acre-feet)

- (1) Test flood surcharge (net): 1,060 at El
819.2
- (2) Top of dam: 3,915
- (3) Flood control pool: N/A
- (4) Recreation pool: N/A
- (5) Spillway crest: 2,700 (with 18-inch
flashboards)

f. Reservoir Surface (acres)

- *(1) Top dam: 171
- *(2) Maximum pool: 171

*Based on the assumption that the surface area will not significantly increase with changes in reservoir elevation from 813.0 to 820.1.

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(3) Flood-control pool: N/A

(4) Recreation pool: 171

(5) Spillway crest: 171

g. Dam

(1) Type: Main dam: earthfill
Dike: earthfill

(2) Length: Main dam: 1,120 feet
Dike: 210 feet

(3) Height: Main dam: 39 feet - maximum
Dike: 7 feet - maximum

(4) Top width: Main dam: 25 feet
Dike: 27 feet

(5) Side slopes: Main dam - Upstream: 2:1
Downstream: 2 to 2.5:1
Dike - Upstream: 3:1
Downstream: 2:1

(6) Zoning: Unknown

(7) Impervious core: Shown on plan (Figure B-2) but no additional information.

(8) Cutoff: Unknown

(9) Grout curtain: Unknown

i. Spillway

(1) Type: Broad-crested weir - flashboards

(2) Length of weir: 35 feet

(3) Crest elevation: 813.0
814.5 (top of
flashboards)

(4) Gates: None

(5) Upstream channel: Stone pavement, and
concrete wingwalls.

(6) Downstream channel: Concrete channel
with vertical walls; maximum 35 feet
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wide, 3 feet deep. Channel is 120 feet long, then changes to stone pavement and natural stream bed.

- j. Regulating Outlets. The low level outlet at the dam is not visible, but is reported operated by a gate valve accessible through a manhole on the crest. The outlet at the dike consists of a concrete gate house built over an open, rectangular well. Two outlets controlled by a slide gate allow flow to enter the 30-inch cast-iron outlet pipe which leads to the distribution pool about 1,000 feet downstream.

SECTION 2

ENGINEERING DATA

- 2.1 General. The only plans available for Kendall Reservoir Dam are a plan of the spillway and embankment, dated 1905, and two plans of the Asnebumskit Canal, Headworks, and spillway, dated 1906. There are no plans for the dike. There are no specifications or computations available from the Owner, State, or County offices, relative to the design and construction of the dam or dike. The remaining data available for this evaluation were visual observations made during inspection, review of previous inspection reports, and conversations with City, State, and County personnel.

We acknowledge the assistance and cooperation of personnel of the Massachusetts Department of Public Works: Messrs. Willis Regan and Raymond Rochford, and of the Massachusetts Department of Environmental Quality Engineering, Division of Waterways: Messrs. John J. Hannon and Joseph Iagallo.

Also, we acknowledge the cooperation and assistance of personnel from the Worcester County Engineer's Office: Messrs. John O'Toole, Joseph Brazauskas, and Mr. Wallace Lindquist - recently retired from county service.

Mr. Kenneth Starbard, and personnel from the Worcester Department of Public Works Operations-Water, provided information on the construction, history, and operation of the dam.

- 2.2 Construction Records. There are no construction records available.
- 2.3 Operating Records. Operation records are kept at the Department of Public Works office in Worcester. These are daily reports of water level, storage volume, rainfall, pumping rates from Quinapoxet Reservoir, depth of flow over weir, and volume of overflow into Wachusett Reservoir.

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2.4 Evaluation

- a. Availability. There is very little engineering data available for this dam. The Department of Public Works file is incomplete.
- b. Adequacy. The lack of in-depth engineering data did not allow for a definitive review. Therefore the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and engineering judgment.
- c. Validity. The 1905 drawing of Kendall Dam was compared to the existing conditions at the site. Apparently the gate house shown on the plan was never constructed. This and other minor discrepancies suggest that the drawing is not entirely valid.

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SECTION 3
VISUAL INSPECTION

3.1 Findings

- a. General. The Phase I Inspection of the dam and dike at Kendall Reservoir was performed on September 13, 1978. A copy of the inspection checklist is in Appendix A. Previous inspections of this dam have been made by others since 1924. A partial listing of these inspections is in Appendix B. Copies of the 1973 inspection reports by the Massachusetts Department of Public Works for both the dam and the dike are also included in Appendix B.
- b. Dam. The earthfill dam at the north end of the reservoir is in good condition. The major area of concern is the seepage about 55 feet beyond the downstream toe of the dam. This seepage occurs in the woods, in the vicinity of the buried concrete headwall of the low-level outlet. Slight settlement of the crest was noted along the alignment of the outlet pipe. A second area of slight seepage was noted at the downstream toe of the embankment, to the left of the spillway. In addition, a number of animal burrows were apparent on the crest and downstream slope of the dam. Otherwise the embankment is flat, straight, and free of trees and brush. The riprapped upstream slope of the dam is in very good condition. Generally, the embankment appears to be well-maintained by the Owner.
- c. Appurtenant Structures. The spillway at Kendall Dam is in poor condition due to deterioration of the concrete. The side walls, from the approach to the discharge channel, show severe spalling and efflorescence. The reinforcing is visible in many locations, and beginning to rust, and the crumbled concrete is accumulating on the floor of the spillway. Minor amounts of grass are growing in the construction joints on the concrete slab, and along the base of the side walls. The rest of the channel floor is in

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good condition and clear of debris and vegetation. The flashboards are in place, and appear to be in good condition.

The low-level outlet structure at the dam could not be inspected. The inlet is submerged in the reservoir, and although the access manhole was opened, the gate valve was not visible from the ground surface. The head-wall for the conduit outlet is buried under accumulated dirt and debris, and there are signs of seepage in the area. Apparently the outlet has not been used in many years. The force main which conducts water from Quinapoxet and Pine Hill Reservoirs is located near the right abutment, but the pipe is buried and the outlet in Kendall Reservoir is submerged.

The side channel spillway at the right abutment of the dam discharges water from the Asnebumskit Canal. The stone cascade on this spillway is in good condition, with only a few weeds growing between the stones. The concrete lining of the canal is also in good condition.

The dike and water supply outlet are located at the southern end of Kendall Reservoir. The earthfill dike ties into natural ground at both abutments. The crest is flat and clear of brush and trees. A concrete stairway is located on the downstream slope. The riprap on the upstream slope is in good condition, and supports only small amounts of vegetation.

The gate house at the dike was opened by the Supervisor of Water Supply for a brief inspection. Two slide gates regulate flow from the reservoir to the gate house well. Screens are used in the influent channels to collect floating debris. The screens are checked daily and cleaned if necessary.

- d. Reservoir Area. Since Kendall Reservoir is used for a public drinking water supply, development is prohibited near the reservoir. All the shorefront property is owned by the City of Worcester. The entire drainage area is hilly woodland, with only a very few houses.

KENDALL RESERVOIR DAM

State Route 31 (South Road) crosses the reservoir near its southern end. The only other road in the watershed is the private property of the Worcester Department of Public Works.

- e. Downstream Channel. Discharge from the spillway flows down the rectangular concrete-lined channel, over a short section of rock pavement, and into the natural stream channel. The channel is free of debris, and relatively clear of vegetation. The stream continues through woodland to Eagle Lake, about 1,500 feet north of the dam.

- 3.2 Evaluation. The dam and dike at Kendall Reservoir appear to be in good condition. However, the seepage through the downstream toe of the dam indicates a potentially hazardous situation, and the spillway is in a deteriorated condition. These structures are not adequately maintained. Recommended measures to improve these conditions are stated in Section 7.3.

SECTION 4

OPERATING PROCEDURES

- 4.1 Procedures. The storage in Kendall Reservoir is carefully controlled by the Department of Public Works Operations-Water, as it is a significant element in the public water supply system of the City of Worcester. Conduits, both pipeline and open canal, connected to the reservoir, supply water either by gravity from Pine Hill Reservoir in the west, or by pumping from Quinapoxet Reservoir, north of Kendall Reservoir. In addition, it is possible for the operators to reverse the process and pump water back up to Pine Hill Reservoir when necessary. Water stored in Kendall Reservoir is allowed to flow through the 30-inch pipe at the southern outlet to a distribution pool about 1,000 feet downstream. The water flows from the pool, which is also used for gaging flow in an open channel to Holden Reservoir No. 1. The purpose of the procedure is to: 1) maintain the maximum safe storage in all five reservoirs in the system, and at the same time prevent waste by overflow out of the watershed via the spillways, and 2) maintain a high water level in Holden Reservoir No. 2, the last reservoir in the system which serves the City of Worcester.

Daily records of operating procedures are maintained by the Worcester Department of Public Works.

- 4.2 Maintenance of Dam. The Supervisor of Water Supply for the Worcester Department of Public Works retains a staff for maintenance of the dam and related facilities. The regular work consists of mowing the grass on both the dam and the dike, removing brush and debris from firelanes, brooks, and the spillway channel, and clearing dead wood from the watershed area, as well as regulating the water levels in the reservoirs.
- 4.3 Maintenance of Operating Facilities. The screens at the gate house are checked daily and cleaned if necessary.

KENDALL RESERVOIR DAM

- 4.4 Description of Any Warning System in Effect.
There are no warning systems in effect at this dam.
- 4.5 Evaluation. An effective operating program has been developed for ensuring a constant supply of water to the City of Worcester. Maintenance of the dam and watershed is regularly scheduled, however, more attention should be paid to the maintenance of appurtenances - particularly the spillway and low-level outlet. In addition, the need for an emergency warning procedure is evident, considering that the dam is in the "high" hazard category. Recommendations for a more thorough maintenance program and a warning system are included in Section 7.3.

SECTION 5

HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

- a. Design Data. The probable maximum flood (PMF) rate was determined to be 2,000 cfs per square mile. This calculation is based on an average drainage area slope of 6.6 percent, the pond-plus-swamp area to drainage area ratio of 14 percent, and the U.S. Army Corps of Engineers' Flow Rates (dated December 1977). Applying the full PMF rate to the 1.89 square miles of drainage area results in a calculated peak flood flow of 3,780 cfs as the inflow test flood. By adjusting the inflow test flood for surcharge storage, the maximum discharge rate was established as 1,700 cfs (900 cfs per square mile) with the water surface at El 819.2. During peak outflow, the spillway (without flashboards) would be discharging 100 percent of the surcharge, and about one foot of freeboard would remain at the dam. Hydraulic analyses indicate that the spillway has the capacity to discharge up to 2,022 cfs at reservoir El 820 (approximately the top of the dam).
- b. Experience Data. The daily operating records for the 1938 and 1955 floods were reviewed at the Department of Public Works office. These indicated that the dam was not overtopped in either storm.
- c. Visual Observations. At the time of the inspection the water level in the reservoir was almost 2 feet below the crest of the spillway. The concrete on the spillway and particularly on the sidewalls is badly spalled. Although this condition is not particularly hazardous at this time, it should be corrected as continued deterioration could result in collapse of the spillway walls. Also, the low-level outlet at the dam was blocked with soil and debris. This should be cleared to allow the

KENDALL RESERVOIR DAM

- d. Overtopping Potential. As noted previously, neither the dam nor the dike would be overtopped by the test flood. Were the dam to fail, the initial outflow would be in the order of 45,000 cfs, producing an initial wave with a height of 13 feet at a velocity of 10 feet per second.

It would take 2.2 hours for the reservoir to drain, and the flood would flow to Eagle Lake.

KENDALL RESERVOIR DAM

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

- a. Visual Observations. The evaluation of the stability of Kendall Reservoir dam and dike is based on the visual inspection conducted on September 13, 1978. As discussed in Section 3, Visual Inspection, the embankments appear to be in good condition. However, the seepage near the downstream toe and the numerous animal burrows indicate a possibly hazardous situation.
- b. Design and Construction Data. There is only one plan available on the design of this dam. This plan (Figure B-2) shows a core wall of unidentified composition. The validity of this drawing is in question, however, because it also shows a two-story gate chamber which does not exist at this time. Furthermore, information does not appear to exist on the type, shear strength, and permeability of the soil and/or rock materials of the embankment.
- c. Operating Records. There is no evidence that instrumentation of any type was ever installed in Kendall Reservoir Dam. The performance of this dam under prior loading can only be inferred by physical evidence at the site.
- d. Post-Construction Changes. There are no as-built drawings available for Kendall Reservoir Dam.
- e. Seismic Stability. The dam is located in Seismic Zone No. 2 and in accordance with Phase I "Recommended Guidelines" does not warrant seismic analyses.

KENDALL RESERVOIR DAM

SECTION 7

ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

- a. Condition. Kendall Reservoir Dam was neither designed nor constructed according to the current approved state-of-the-art procedures. Based on the visual inspection of the site, there are areas of concern which must be corrected to assure the continued performance of this dam. Generally, the dam is considered to be in good condition. The major problems are the deteriorated concrete on the spillway, and the seepage at the downstream toe of the dam, near the buried outlet headwall.

Hydraulic analyses indicate that the spillway without flashboards can discharge a flow of 1,700 cfs (the full test flood) without overtopping the dam.

- b. Adequacy. The lack of in-depth engineering data did not allow for a definitive review. Therefore the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and engineering judgment.
- c. Urgency. The recommendations and remedial measures outlined below should be implemented by the Owner within two years after receipt of this Phase I Inspection Report. However, repair of the concrete walls and floor of the spillway should be undertaken within one year.
- d. Need for Additional Investigations. Additional investigations to further assess the adequacy of the dam are outlined below in Section 7.2, Recommendations.

- 7.2 Recommendations. In view of the concerns over the continued performance of the dam it is recommended that the Owner employ a qualified consultant to investigate the seepage at the toe of the dam.

KENDALL RESERVOIR DAM

The recommendations on repairs and maintenance procedures are outlined below under Section 7.3, Remedial Measures.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. The ground and embankments of the dam and dike are well maintained. However, it is recommended that the Owner add the following items to the maintenance program:

- (1) rebuild or repair the concrete sidewalls to the spillway, and resurface the floor of the channel
- (2) replace the "permanent" flashboards with collapsible flashboards designed to break away during periods of high flow or remove the flashboards,
- (3) remove the debris from the low-level outlet, and clear the trees away from the toe to expose the seepage area,
- (4) fill in the animal burrows on the crest and downstream slopes of both the dam and the dike,
- (5) all repairs and maintenance should be undertaken in accordance with all applicable State regulations,
- (6) institute a definite plan for surveillance and a warning system during periods of unusually heavy rains and/or runoff,
- (7) technical inspections of this dam should be conducted on a bi-annual basis.

7.4 Alternatives. An alternative to implementing the recommendation and the maintenance procedures itemized above would be to lower the water level in the reservoir.

KENDALL RESERVOIR DAM

APPENDIX A
PERIODIC INSPECTION
CHECKLIST

KENDALL RESERVOIR DAM

PERIODIC INSPECTION

PARTY ORGANIZATION

PROJECT Kendall Reservoir

DATE 13 Sept. 1978

TIME 1:00 pm

WEATHER sunny, 70°

W.S. ELEV. 811.7 U.S. - DN.S.

PARTY:

Assumed benchmark El 813 on crest of spillway. Based on USGS topographic map

<u>Ed Greco</u>	6.	
<u>Susan Pierce</u>	7.	
<u>Dan Bornstein</u>	8.	
<u>Lyle Branagan</u>	9.	
	10.	

PROJECT FEATURE	INSPECTED BY	REMARKS
<u>Dam / Dike</u>	<u>E. Greco / S. Pierce</u>	
<u>Spillway / Gate</u>	<u>L. Branagan / D. Bornstein</u>	

PERIODIC INSPECTION CHECK LIST

PROJECT Kendall Dam DATE 9-13-78
 PROJECT FEATURE Dam NAME E. Greco
 DISCIPLINE Geotechnical NAME S. Pierce

Note: d/s = downstream u/s = upstream

AREA EVALUATED	CONDITIONS
<u>DAM EMBANKMENT</u>	
Crest Elevation	Downstream side of crest higher than upstream. varies from 819.7 to 821
Current Pool Elevation	811.7
Maximum Impoundment to Date	unknown
Surface Cracks	none visible
Pavement Condition	grass crest / 3 manholes on crest, 2-100' from right abutment, 1-400' from rt abt.
Movement or Settlement of Crest	small hole on crest
Lateral Movement	none visible
Vertical Alignment	relatively flat
Horizontal Alignment	relatively straight
Condition at Abutment and at Concrete Structures	abutments tie into natural ground
Indications of Movement of Structural Items on Slopes	none
Trespassing on Slopes	wood chuck holes near left spillway abutment
Sloughing or Erosion of Slopes or Abutments	none
Rock Slope Protection - Riprap Failures	riprap on upstream slope in good condition
Unusual Movement or Cracking at or near Toes	none
Unusual Embankment or Downstream Seepage	55' from d/s toe: slight seep in vicinity of buried concrete headwall, in line with outlet manhole. D/s toe at left end of dam wet.
Piping or Boils	settlement visible along crest from manhole to buried headwall
Foundation Drainage Features	none visible
Toe Drains	none visible
Instrumentation System	unknown

PERIODIC INSPECTION CHECK LIST

PROJECT Kendall

DATE 9-13-78

PROJECT FEATURE Dike

NAME E. Greco

DISCIPLINE Geotechnical

NAME S. Pierce

AREA EVALUATED	CONDITION
<u>DIKE EMBANKMENT</u>	Earth fill dike at south end of Kendall Reservoir
Crest Elevation	820.8 to 823.0
Current Pool Elevation	811.7
Maximum Impoundment to Date	unknown
Surface Cracks	none
Pavement Condition	grass crest
Movement or Settlement of Crest	none - minor irregularities to surface
Lateral Movement	none visible
Vertical Alignment	relatively flat
Horizontal Alignment	relatively straight
Condition at Abutment and at Concrete Structures	no concrete. Dike ties into natural ground at both abutments. possible bedrock outcrop at left abutment
Indications of Movement of Structural Items on Slopes	none
Trespassing on Slopes	none, concrete steps on d/s face of dam
Sloughing or Erosion of Slopes or Abutments	none; separation between mortared riprap and gatehouse
Rock Slope Protection - Riprap Failures	riprap on u/s slope, grouted only in vicinity of gate structure
Unusual Movement or Cracking at or near Toes	none visible
Unusual Embankment or Downstream Seepage	none
Piping or Boils	none
Foundation Drainage Features	none
Toe Drains	none
Instrumentation System	none

PERIODIC INSPECTION CHECK LIST

PROJECT Kendall Reservoir

DATE 9-13-78

PROJECT FEATURE Gate House

NAME L. Branagan

DISCIPLINE _____

NAME D. Bornstein

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - CONTROL TOWER</u>	Paired concrete superstructure and foundation, built on end of earth berm.
a. Concrete and Structural	Concrete headwall at ups face of structure
General Condition	good - minor exposed aggregate at water line
Condition of Joints	good
Spalling	none
Visible Reinforcing	none
Rusting or Staining of Concrete	none
Any Seepage or Efflorescence	minor efflorescence at water line
Joint Alignment	good
Unusual Seepage or Leaks in Gate	gate not visible
Cracks	none
Rusting or Corrosion of Steel	n/a
b. Mechanical and Electrical	n/a
Air Vents	"
Float Wells	"
Crane Hoist	"
Elevator	"
Hydraulic System	"
Service Gates	"
Emergency Gates	"
Lightning Protection System	"
Emergency Power System	"
Wiring and Lighting System in Gate Chamber	"

PERIODIC INSPECTION CHECK LIST

PROJECT Kendall Reservoir

DATE 9-13-78

PROJECT FEATURE outlet at stilling basin

NAME L. Branagan

DISCIPLINE _____

NAME D. Bornstein

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE * AND OUTLET CHANNEL	
General Condition of Concrete	Good around stilling basin; piers at weir in poor condition
Rust or Staining	weir plate slightly rusted
Spalling	heavy spalling of piers at weir
Erosion or Cavitation	none
Visible Reinforcing	none
Any Seepage or Efflorescence	slight efflorescence at piers
Condition at Joints	n/a
Drain Holes	none
Channel	stone-masonry side walls, 2' wide, 1-3' high extend 50 feet d/s of weir
Loose Rock or Trees Over- hanging Channel	none
Condition of Discharge Channel	natural stone and gravel pavement, some weeds growing in channel near u/s end

30-inch cast iron outlet pipe from gate house to stilling basin

Basin is concrete-lined with iron weir plate

Outlet pipe stands vertically (submerged) in center of basin

PERIODIC INSPECTION CHECK LIST

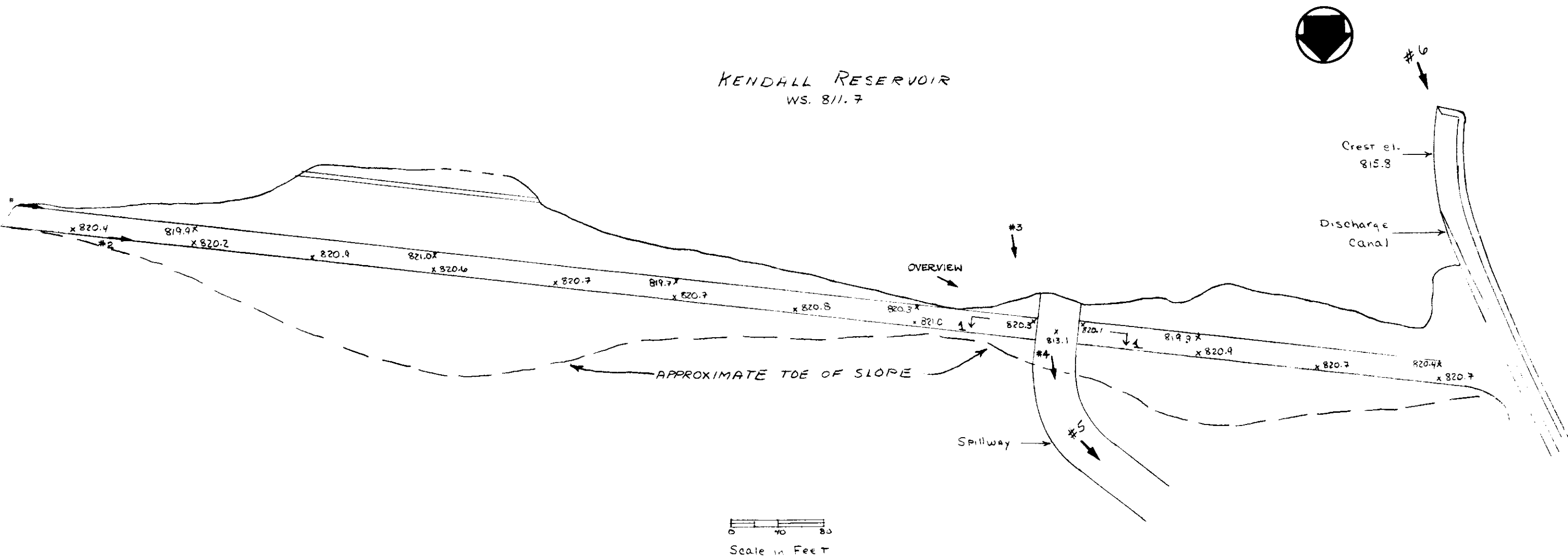
PROJECT Kendall Reservoir DATE 9-13-78
 PROJECT FEATURE Spillway NAME L. Branagan
 DISCIPLINE Hydraulics NAME D. Bornstein

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS</u>	
a. Approach Channel	earth with random stone and cobbles; concrete training walls
General Condition	channel in fair condition; walls in very poor condition - concrete spalled
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	none
Floor of Approach Channel	earth
b. Weir and Training Walls	flat concrete slab with concrete walls, concrete pedestrian bridge arches over spillway
General Condition of Concrete	weir - fair walls - very poor
Rust or Staining	slight, visible on reinforcing
Spalling	severe
Any Visible Reinforcing	yes, in numerous locations
Any Seepage or Efflorescence	severe efflorescence; no seepage
Drain Holes	none
c. Discharge Channel	concrete channel changes to earth channel
General Condition	walls in very poor condition
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	none
Floor of Channel	concrete slabs change to earth channel
Other Obstructions	none

APPENDIX B

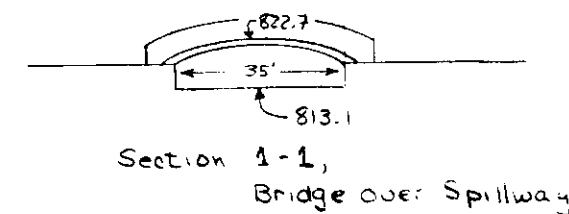
PLAN OF DAM AND PREVIOUS INSPECTION REPORTS

	<u>Page</u>
Figure B-1. Plan of Dam, 1978 Survey	B-1
Figure B-2. Plan of Dam	B-2
Figure B-3. Plan of Dike	B-3
Figure B-4. Plan of Canal at Dam	B-4
Previous Inspections (Partial Listing)	B-5
Inspection Reports by Massachusetts Department of Public Works, March, 1973	B-7

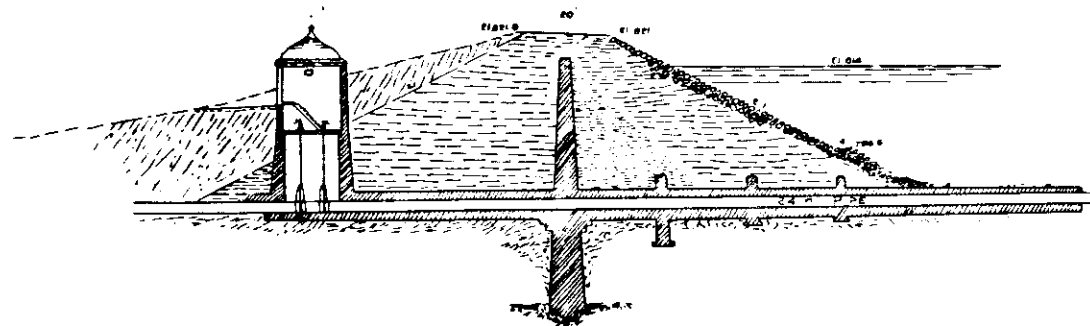
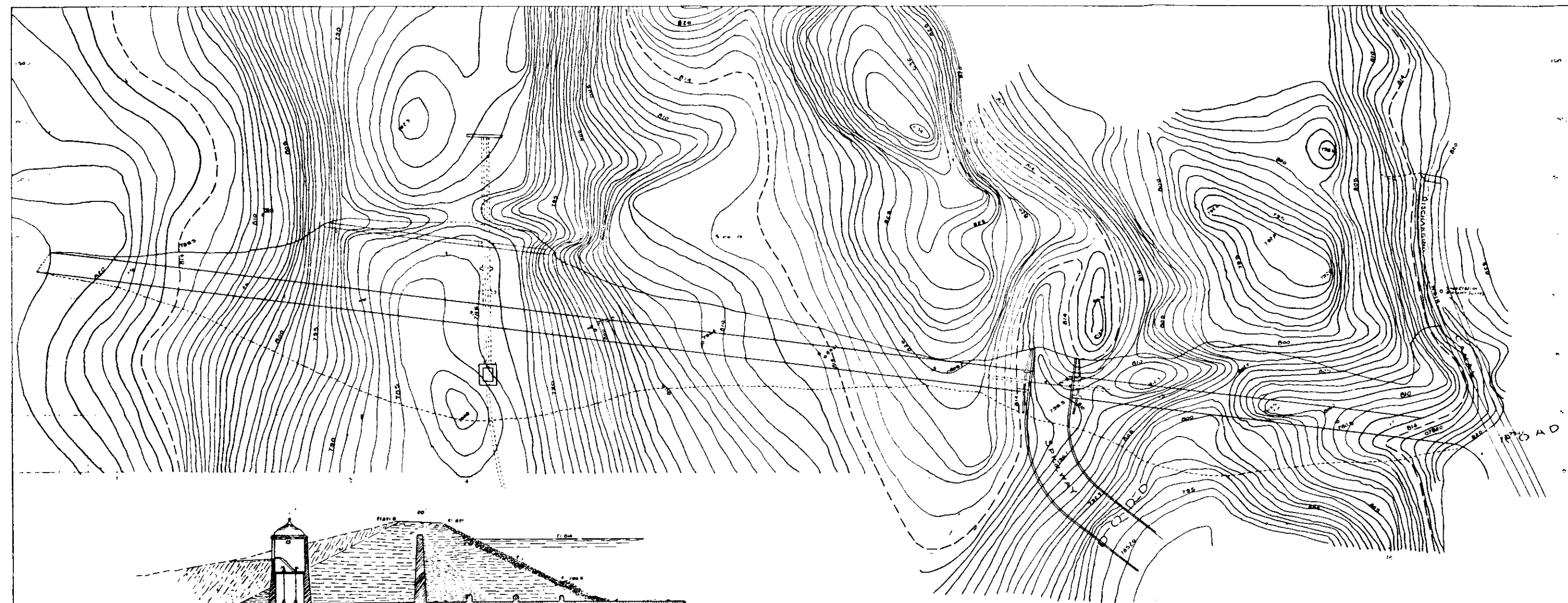


NOTES

- 1) ELEVATIONS shown based on assumed benchmark on Spillway Crest, el. 813.0 (M.S.L.)
- 2) Details shown based on field survey of Sept. 11, 1978, and drawing dated Feb. 16, 1940 by the Worcester County Engineering Department.
- 3) #2 denotes location and view of photographs.

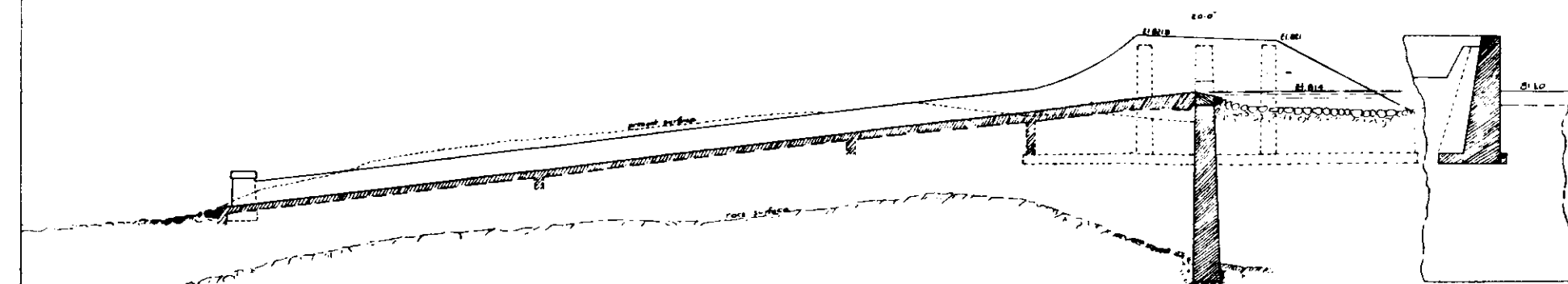


METCALF & EDDY, INC. ENGINEERS BOSTON, MA.	U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MA.
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	
KENDALL RESERVOIR DAM	
FIGURE B-1, PLAN OF DAM	
TRIBUTARY NASHUA RIVER	MASSACHUSETTS
SCALE: 1" = 80'	DATE: NOVEMBER, 1978



SECTION THROUGH DAM

Scale 20' to 1"



SECTION THROUGH SPILLWAY

Scale 10' to 1"

NOTE: THIS DRAWING HAS BEEN
REDUCED 50%.

FRED W. MCCLURE-CITY ENG. MAR. 1905

FIGURE B-2

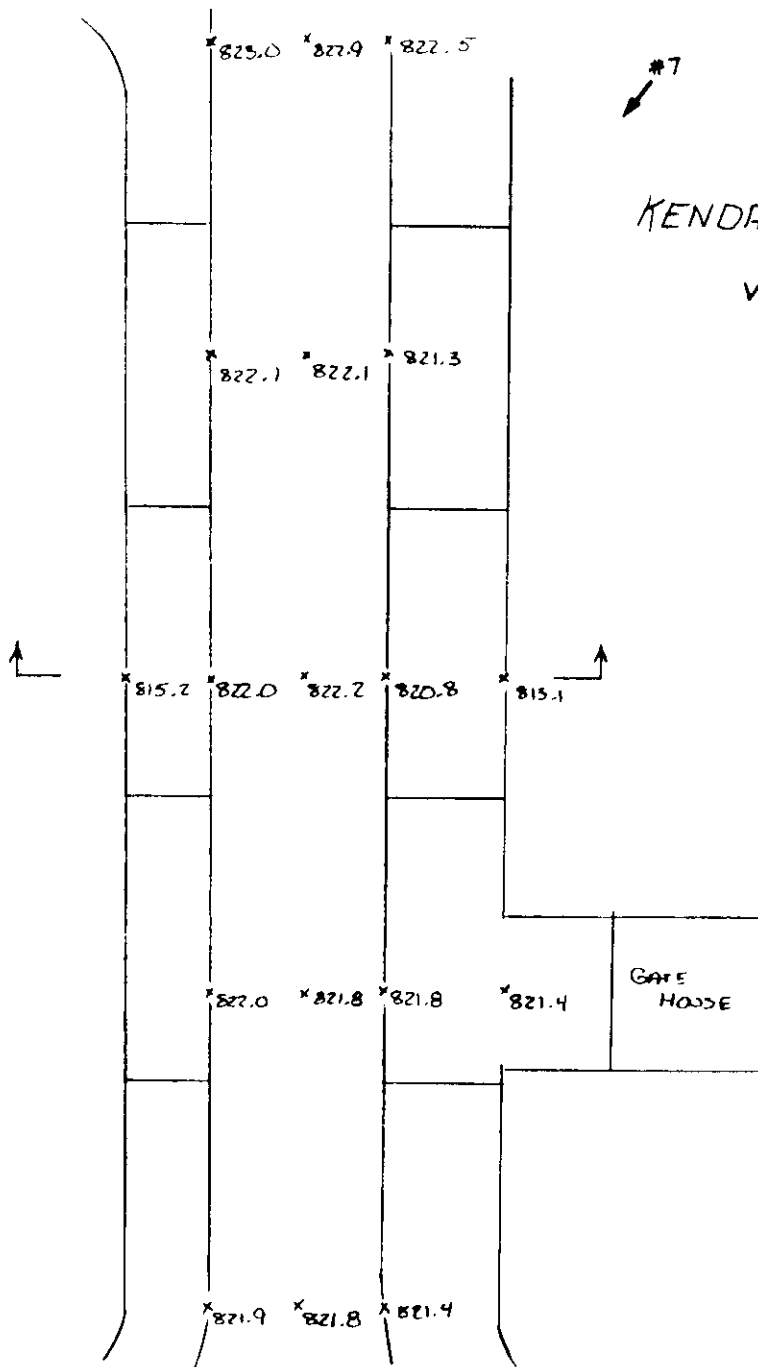
WORCESTER COUNTY COMMISSIONERS
WORCESTER COUNTY ENGINEERING DEPARTMENT
PLAN OF
DAM
KENDALL RESERVOIR
HOLDEN MASS
FOR THE CITY OF WORCESTER
AS FILED AND APPROVED BY THE
COUNTY COMMISSIONERS
DOCKET #464

SCALE AS NOTED

TRACED BY E.G. GORCORAN 2-16-40
TRACING CHECKED BY F.E. PERRY 2-16-40 DAM NO 21-04

APPROVED: MARCH 14, 1911

James Doolittle
George W. Wood
Arthur L. Moore



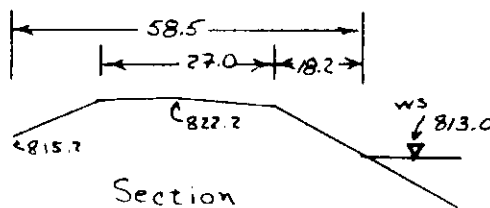
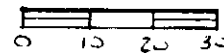
KENDALL RESERVOIR

WS. 813.0

NOTES:

- 1) Elevations shown based on assumed benchmark or spillway crest 813.0 (MSL)
- 2) Information shown from field survey of Sept. 11, 1978
- 3) #7 Shows direction of view of photograph
- 4) See figure B-1 for PLAN OF DAM.

Scale in Feet



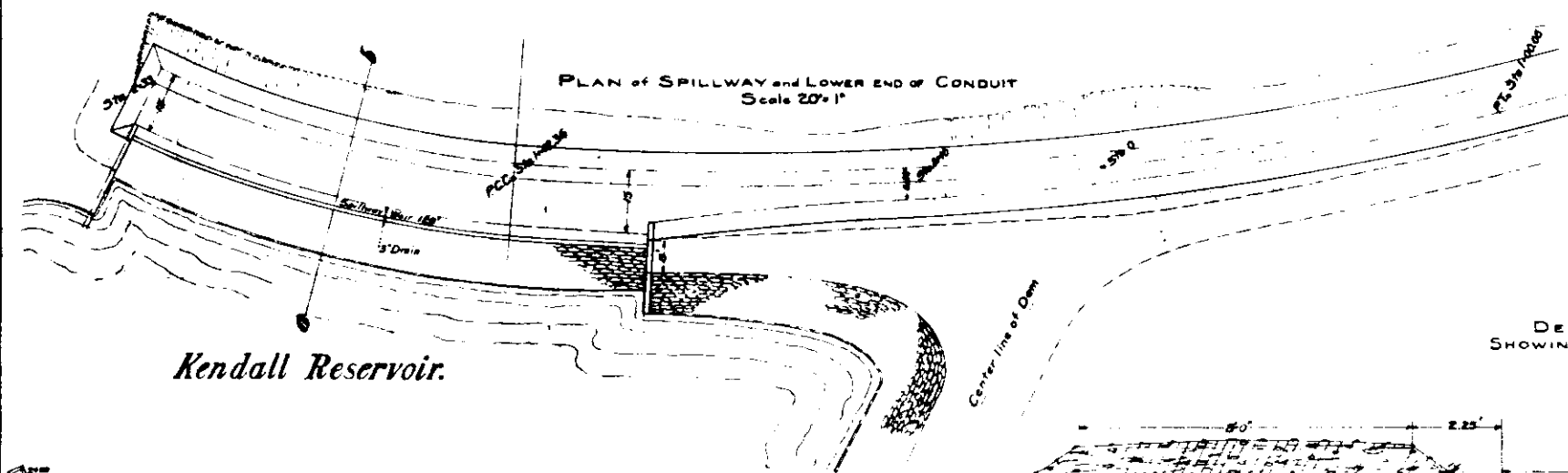
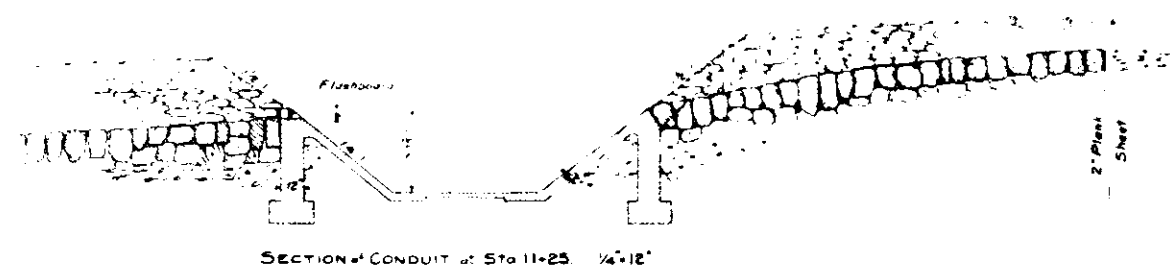
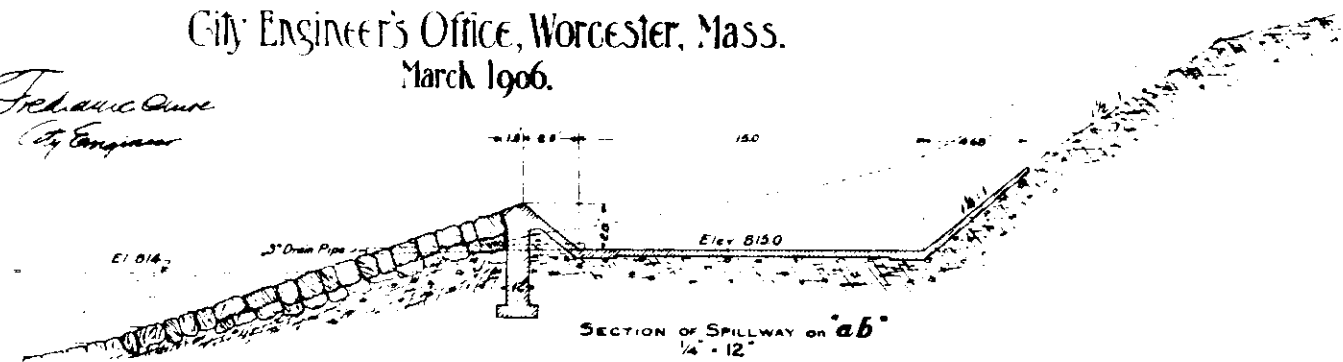
METCALF & EDDY, INC. ENGINEERS BOSTON, MA.	U.S. ARMY ENGINEER DIV. NEW ENGLAND COMPS OF ENGINEERS BALTIMORE, MD.
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	
KENDALL RESERVOIR DAM	
FIGURE B-3, PLAN OF DIKE	
TRIBUTARY NASHUA RIVER	MASSACHUSETTS
SCALE: 1" = 30'	DATE: NOVEMBER, 1978

ASNEBUMSKIT CANAL. W.W.W.

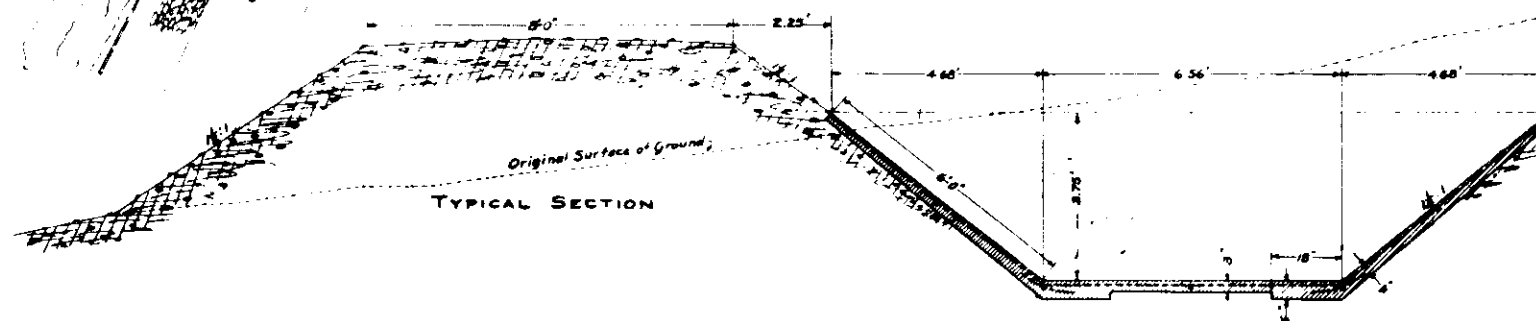
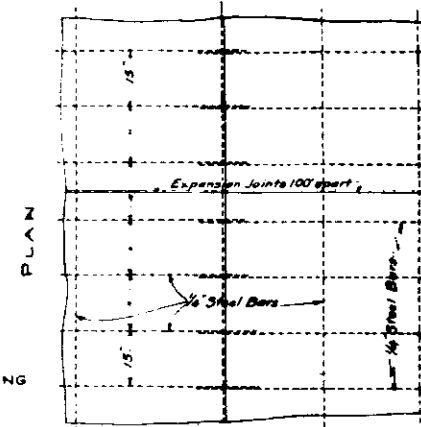
City Engineer's Office, Worcester, Mass.

March 1906.

Frederic Dure
City Engineer

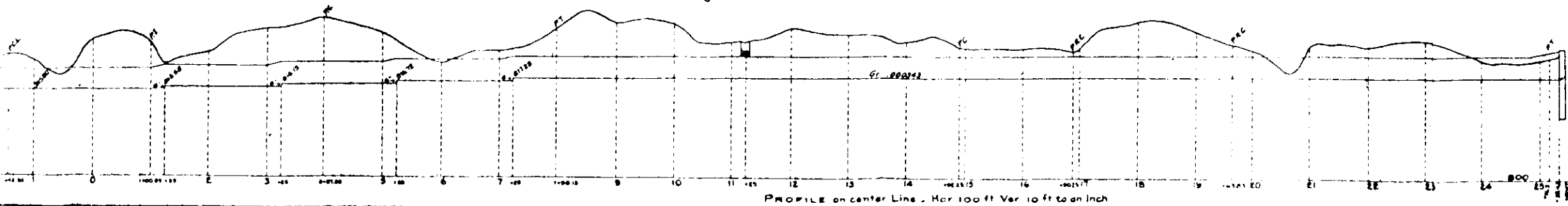
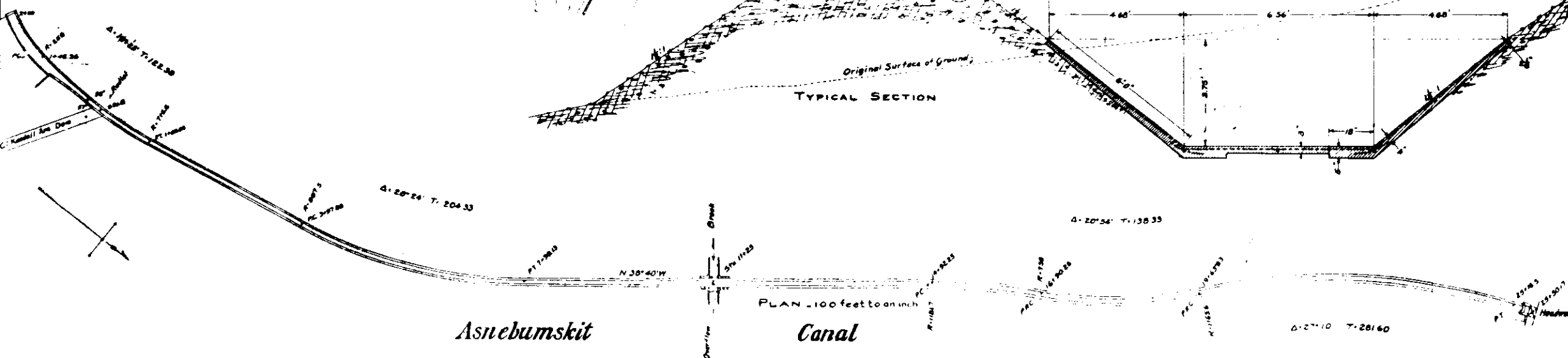


DETAIL of CONDUIT
SHOWING STEEL REINFORCING
1/2" = 12"



NOTE: THIS DRAWING HAS BEEN
REDUCED 50%.

approved March 1906
George W. Cook
Warren Goodale
George L. Clemence
County Commissioners



COPIED FROM ORIGINAL

WORCESTER COUNTY COMMISSIONERS
WORCESTER COUNTY ENGINEERING DEPARTMENT
PLAN OF
CANAL AT DAM
ACROSS ASNEBUMSKIT BROOK
HOLDEN, MASS.
FOR THE CITY OF WORCESTER
AS FILED AND APPROVED BY THE
COUNTY COMMISSIONERS
NOV. 9, 1906
SEPT MEETING DOCKET 399
SCALES AS NOTED

TRACED BY: *John A. Mearns*
TRACING CHECKED BY: *J. C. Mearns*

DAM NO. 21-05

COUNTY ENGINEER

FIGURE B-4

TOWN OR CITY *Holden.*DECREE NO. *464*

PLAN NO.

DAM NO.

*21-01*LOCATION *On Road from Holden to Paxton. - Kendall Brook.* C. C. DOCKET NO.

DESCRIPTION OF DAM

Type *Earthen Dam - Concrete Core Wall.*
 Length *1300.*
 Height *40.*
 Thickness top *20.*
 " bottom *Greatest width bottom = 166.*
 Downstream Slope *2:1*
 Upstream " *Riprap 24" thick 2:1*
 Length of Spillway *Crest 7'6" above - at west end.*
 Size of Gates *Duplicating Gate Valves 24" c.i. w. 175*
 Location of Gates *450' to left Spillway*
 Flashboards used *No.*
 Width Flashboards or Gates
 Dam designed by *City of Worcester.*
 " constructed by
 Year constructed *1912*

GENERAL REMARKS

*Owned by City of Worcester - filed
 with C.C. Records March 14, 1911.
 Vol. 30. P. 440. See City Plan # 2769.
 Inspected Jan. 14, 1924 L.O. Marden.*

" *Aug. 9, 1928* " *O.K.*

" *Nov. 19, 1929 - L. Goodale - R. Dingley*

" *Aug. 24, 1932 - " L.O.M.*

September meeting 1913 work complete

DESCRIPTION OF RESERVOIR & WATERSHED

Name of Main Stream *Kettle (Kendall) Brook*
 " " any other Streams *Asnebumskit by Canal.*
 Length of Watershed
 Width " "
 Is Watershed Cultivated
 Percent In Forests
 Steepness of Slope
 Kind of Soil
 No. of Acres in Watershed *935 S. M.*
 " " " Reservoir
 Length of Reservoir
 Width " "
 Max Flow Cu. Ft. per Sec.
 Head or Flashboards - Low Water
 " " " High " *None*

GENERAL REMARKS

*Inspected: 3-26-37 W. O. Lindquist
 Traced: E. C. Corcoran, Feb. 16, 1940.
 Tracing checked by F.E.P. & D.M. 3-6-1940.
 Inspected: Dec. 27, 1940 - L. H. Spofford.
 " Dec. 7, 1942 - L.O.M. & J.F.C.
 " Sept. 16, 1943 - L.O.M. & Perry & Starbuck.
 " Nov. 18, 1947. " " " Hardy*

2 - Library Bureau 10-92260

PREVIOUS INSPECTIONS (PARTIAL LISTING)

COPY OF INSPECTION CARD ON FILE AT THE MASSACHUSETTS
 DEPARTMENT OF PUBLIC WORKS, DISTRICT OFFICE, WORCESTER.

DAM NO. **21-23**

C. C. DOCKET NO. 6411

DESCRIPTION OF DAM

Type	<i>Earth</i>
Length	
Height	
Thickness top	
" bottom	
Downstream Slope	
Upstream "	
Length of Spillway	
Size of Gates	
Location of Gates	
Flashboards used	
Width Flashboards or Gates	
Dam designed by	
" constructed by	
Year constructed	

GENERAL REMARKS

City of Worcester Water Dept.

Inspected: Dec. 7, 1928 - L. O. Marden
" Nov. 19, 1929 - " " L. Goodale
R. Lingley

" Aug. 24, 1932 " " "
" Mar. 26, 1937 W. O. Lindquist
" Nov. 1, 1943 - LOM.

DESCRIPTION OF RESERVOIR & WATERSHED

Name of Main Stream
 " " any other Streams
 Length of Watershed
 Width " "
 Is Watershed Cultivated
 Percent in Forests
 Steepness of Slope
 Kind of Soil
 No. of Acres in Watershed
 " " " " Reservoir
 Length of Reservoir
 Width " "
 Max Flow Cu. Ft. per Sec.
 Head or Flashboards-Low Water
 " " " " -High "

GENERAL REMARKS

2 - Library Bureau 10-92260

PREVIOUS INSPECTIONS (PARTIAL LISTING)

**COPY OF INSPECTION CARD ON FILE AT THE MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS, DISTRICT OFFICE, WORCESTER.**

Recvd
Div. of W.W.: 1-30-74

FILE *200*

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: City/Town HOLDEN Dam No. 3-14-134-4
Name of Dam KENDALL RES. DAM Inspected by MICHAUD
MULCAHY & KANN
Date of Inspection MARCH 27, 1973

2. Owner/s: per: Assessors _____ Prev. Inspection ✓

Reg. of Deeds _____ Pers. Contact _____

1. CITY OF WORCESTER, FRANCIS J. McGRATH, CITY MANAGER
Name St. & No. City/Town State Tel. No.

2. _____
Name St. & No. City/Town State Tel. No.

3. _____
Name St. & No. City/Town State Tel. No.

3. Caretaker (if any) e.g. superintendent, plant manager, appointed
by absentee owner, appointed by multi owners.

Name: _____ St. & No.: _____

City/Town: _____ State: _____ Tel. No.: _____

4. No. of Pictures taken NONE

5. Degree of Hazard: (if dam should fail completely)*

1. Minor _____ 2. Moderate _____

3. Severe ✓ 4. Disastrous _____

* This rating may change as land use changes (future development)

6. Outlet Control: Automatic _____ Manual _____

NONE Operative _____ yes; _____ No.

Comments: FLASHBOARDS CONTROL HEIGHT OF WATER AT
SPILLWAY

7. Upstream Face of Dam: Condition:

1. Good ✓ 2. Minor Repairs _____

3. Major Repairs _____ 4. Urgent Repairs _____

or Comments:

8. Downstream Face of Dam:

Condition: 1. Good ✓ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

9. Emergency Spillway: NONE

Condition: 1. Good _____ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

10. Water Level at time of inspection: 6 ft. above _____ below ✓
top of dam ✓ principal spillway _____
other _____

11. Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment NO
Animal Burrows and Washouts NO
Damage to slopes or top of dam NO
Cracked or Damaged Masonry YES (see #12)
Evidence of Seepage NO
Evidence of Piping NO
Erosion NO
Leaks NO
Trash and/or debris impeding flow NO
Clogged or blocked spillway NO
Other NO

12. Remarks & Recommendations: (Fully Explain)

THIS DAM IS WELL KEPT BY CITY OF WORCESTER
WATER DEPT. THERE IS SOME SPALLING OF THE
CEMENT CONCRETE WALLS OF THE SPILLWAY.
THIS PRESENTS NO DANGER TO DAM.

13. Overall Condition:

1. Safe ✓
2. Minor repairs needed _____
3. Conditionally safe - major repairs needed _____
4. Unsafe _____
5. Reservoir impoundment no longer exists (explain)
Recommend removal from inspection list _____

Boston Copy

845-S

1.70

DESCRIPTION OF DAM

DISTRICT 3

Submitted by MICHAUD
MULCAHY & KANN Dam No. 3-14-134-4
Date MARCH 27, 1973 City/Town HOLDEN
Name of Dam KENDALL RES. DAM

1. Location: Topo Sheet No. 20 C

Provide 8 $\frac{1}{2}$ " x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: _____ Year/s of subsequent repairs _____

3. Purpose of Dam: Water Supply ☒ Recreational _____

Irrigation _____ Other _____

4. Drainage Area: 9.35 sq. mi. _____ acres

5. Normal Ponding Area: 175 acres; Ave. depth _____

Impoundment: _____ gals.; _____ acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir

NONE i.e. summer homes, etc. _____

7. Dimensions of Dam: Length 1100'± Max. Height 35'±

Slopes: Upstream Face 2:1

Downstream Face 2:1

Width across top 30'±

8. Classification of Dam by Material:

Earth ☒ Conc. Masonry ☒ Stone Masonry _____

Timber _____ Rockfill ☒ Other _____

9. A. Description of present land usage downstream of dam:

90 % rural; 10 % urban.

B. Is there a storage area or flood plain downstream of dam which could accommodate the impoundment in the event of a complete dam failure? yes _____ no ☒.

DAM NO. 3-14-134-4

10. Risk to life and property in event of complete failure.

No. of people 400 ±

No. of homes 50 ±

No. of Businesses 6 ±

No. of industries 1

Type Textile
WATER, GAS
Type SEWER, TEL, Elec.

No. of utilities 5

Railroads 1

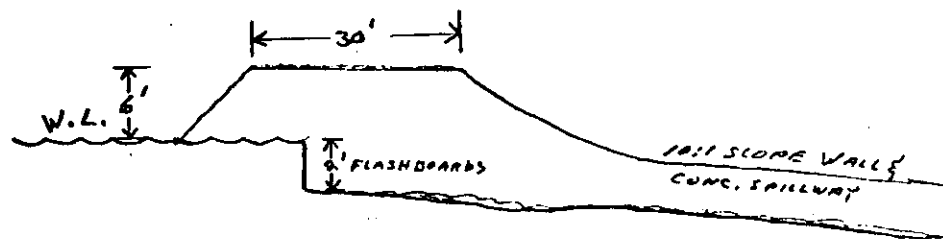
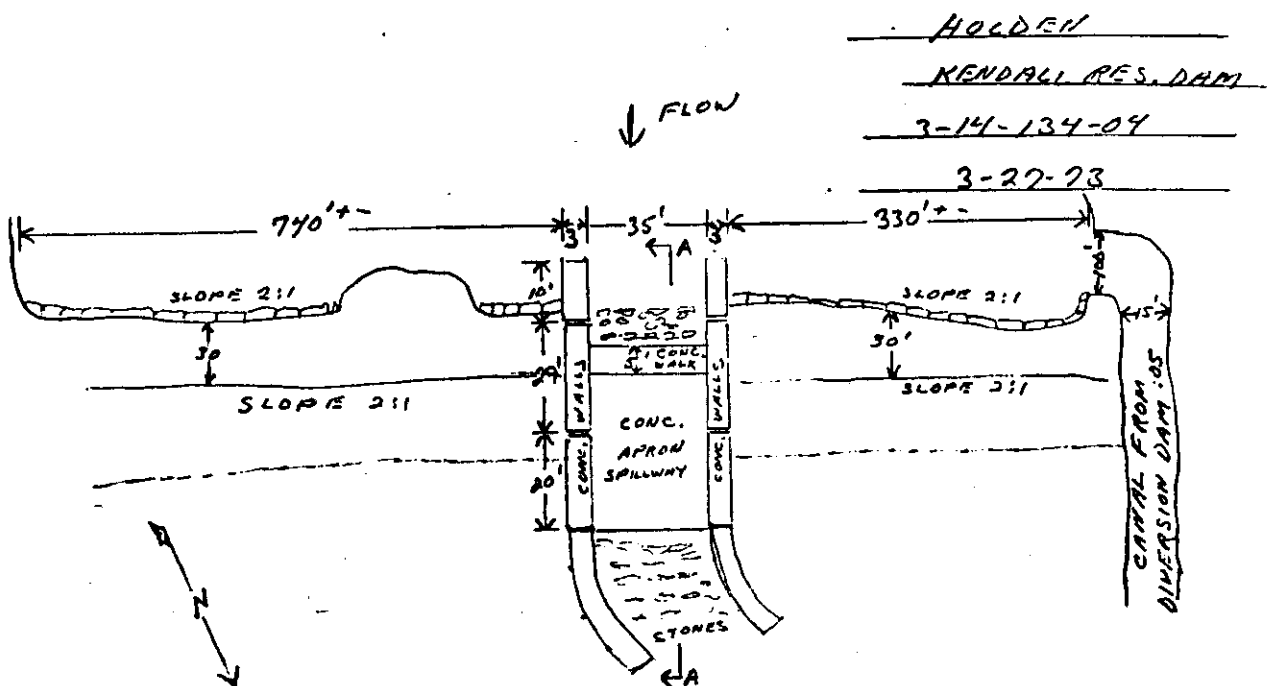
Other dams 3-14-134-0711

Other None

11. Attach Sketch of dam to this form showing section and plan on 8½" x 11" sheet.

12. How to Locate:

FROM RTE #122A HEADING N'WLY TAKE A LEFT
ON KENDALL ROAD TO END, DAM ON LT.



SECTION A-A

Recvd
Div. of W.W. 1-30-74

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: City/Town HOLDEN Dam No. 3-14-134-044

Name of Dam KENDALL RES. DAM Inspected by ED. MULCAHY
MAURIN R. MICHARD

Date of Inspection 3-27-73

2. Owner/s: per: Assessors _____ Prev. Inspection ✓

Reg. of Deeds _____ Pers. Contact _____

1. CITY OF WORCESTER FRANCIS J. McGRATH, CITY MANAGER
Name _____ St. & No. _____ City/Town State Tel. No. _____

2. _____
Name _____ St. & No. _____ City/Town State Tel. No. _____

3. _____
Name _____ St. & No. _____ City/Town State Tel. No. _____

3. Caretaker (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Name: _____ St. & No.: _____

City/Town: _____ State: _____ Tel. No.: _____

4. No. of Pictures taken NONE

5. Degree of Hazard: (if dam should fail completely)*

1. Minor ✓ 2. Moderate _____

3. Severe _____ 4. Disastrous _____

* This rating may change as land use changes (future development)

6. Outlet Control: Automatic NONE Manual _____

Operative _____ yes; _____ No.

Comments:

7. Upstream Face of Dam: Condition:

1. Good ✓ 2. Minor Repairs _____

3. Major Repairs _____ 4. Urgent Repairs _____

or Comments:

8. Downstream Face of Dam:

Condition: 1. Good ✓ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

9. Emergency Spillway: NONE

Condition: 1. Good _____ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

10. Water Level at time of inspection: 4 ft. above _____ below ✓
top of dam ✓ principal spillway _____
other _____

11. Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment NONE
Animal Burrows and Washouts NONE
Damage to slopes or top of dam NONE
Cracked or Damaged Masonry NONE
Evidence of Seepage NONE
Evidence of Piping NONE
Erosion NONE
Leaks NONE
Trash and/or debris impeding flow NONE
Clogged or blocked spillway NONE
Other NONE

12. Remarks & Recommendations: (Fully Explain)

THIS STRUCTURE IS A CAUSEWAY WITH
EQUALIZER CULVERTS. NO WATER IS IMPOUN-
DED. RECOMMEND REMOVAL FROM IN-
SPECTION LIST.

13. Overall Conditions:

1. Safe ✓
2. Minor repairs needed _____
3. Conditionally safe - major repairs needed _____
4. Unsafe _____
5. Reservoir impoundment no longer exists (explain)
Recommend removal from inspection list Yes

OK.

Boston Copy

DESCRIPTION OF DAM

DISTRICT 3

Submitted by MICHAUD
MULCAHY & KANN

Dam No. 3-14-134-04A

Date MARCH 27 1973

City/Town MILDEN

Name of Dam KENDALL RES. DAM

1. Location: Topo Sheet No. 20 C

Provide 8 1/2" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: _____ Year/s of subsequent repairs _____

3. Purpose of Dam: Water Supply ☒ Recreational _____

Irrigation _____ Other _____

4. Drainage Area: 7.5 sq. mi. _____ acres

5. Normal Ponding Area: 1 acres; Ave. depth _____

Impoundment: _____ gals.; _____ acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir

NONE i.e. summer homes, etc. _____

7. Dimensions of Dam: Length 700' ± Max. Height 4'

Slopes: Upstream Face 1:1

Downstream Face 1:1

Width across top 47'

8. Classification of Dam by Material:

Earth ☒ Conc. Masonry _____ Stone Masonry _____

Timber _____ Rockfill _____ Other _____

9. A. Description of present land usage downstream of dam:

100 % rural; _____ % urban.

B. Is there a storage area or flood plain downstream of dam which could accomodate the impoundment in the event of a complete dam failure? yes ☒ no _____

DAM NO. 3-14-134-04A

10. Risk to life and property in event of complete failure.

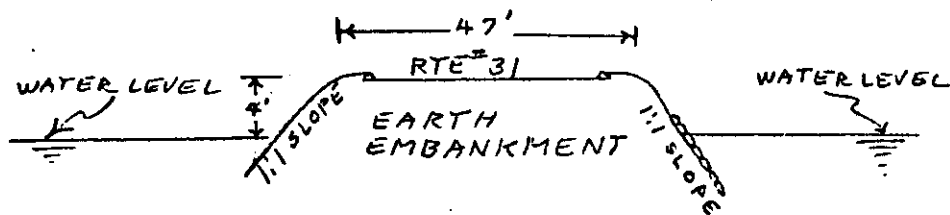
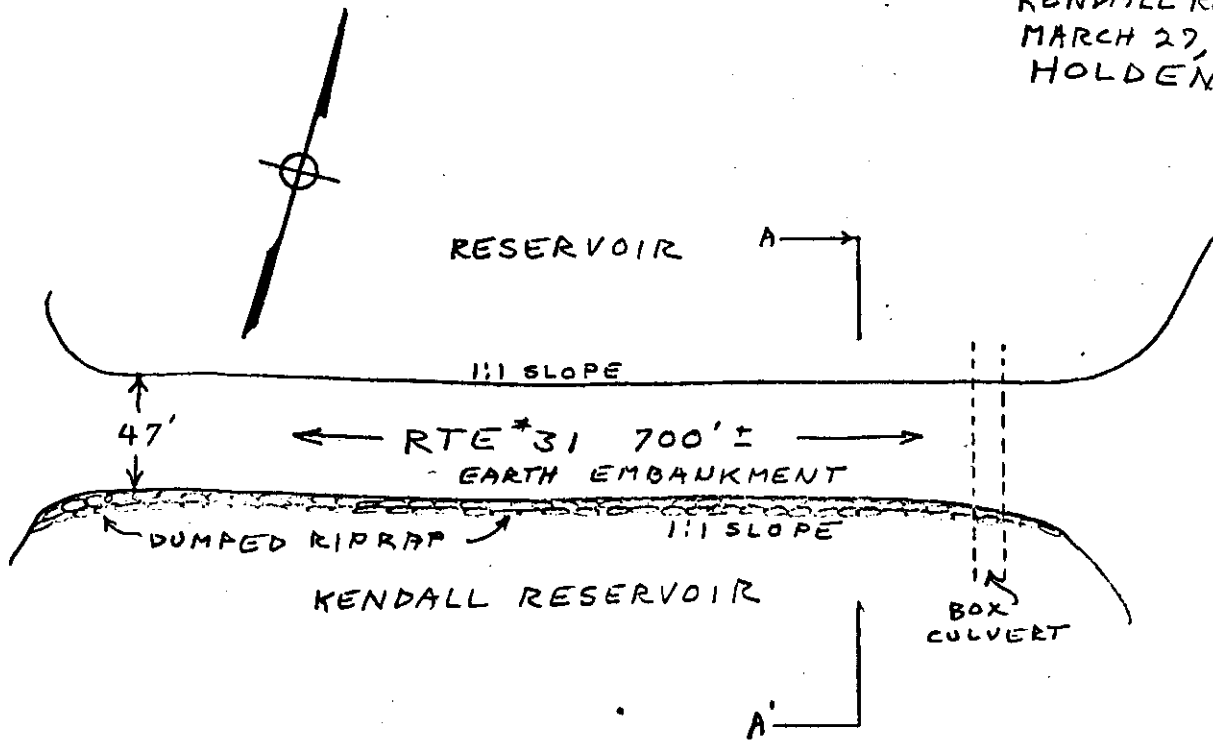
No. of people NONE.
No. of homes NONE.
No. of Businesses NONE.
No. of industries NONE. Type _____
No. of utilities NONE. Type _____
Railroads NONE.
Other dams NONE.
Other NONE.

11. Attach Sketch of dam to this form showing section and plan on 8 $\frac{1}{2}$ " x 11" sheet.

12. How to Locate:

FROM HOLDEN CENTER TAKE 31 WEST
TO RESERVOIR + DAM

DAM#3-14-134-41
KENDALL RES. DAM
MARCH 27, 1973
HOLDEN



SECTION A-A'

Recvd
Div. of W.W. 1-30-74

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: City/Town HOLDEN Dam No. 3-14-134-4.1
Name of Dam DAM BELOW KENDALL RES. Inspected by MICHAUD
MILCAMPY & KANN
Date of Inspection MARCH 28, 1973

2. Owner/s: per: Assessors _____ Prev. Inspection ☒

Reg. of Deeds _____ Pers. Contact _____

1. CITY OF WORCESTER FRANCIS V. McGRATH CITY MANAGER
Name St. & No. City/Town State Tel. No.
2. _____
Name St. & No. City/Town State Tel. No.
3. _____
Name St. & No. City/Town State Tel. No.

3. Caretaker (if any) e.g. superintendent, plant manager, appointed
by absentee owner, appointed by multi owners.

Name: _____ St. & No.: _____
City/Town: _____ State: _____ Tel. No.: _____

4. No. of Pictures taken NONE

5. Degree of Hazard: (if dam should fail completely)*

1. Minor ☒ 2. Moderate _____
3. Severe ☒ 4. Disastrous _____

* This rating may change as land use changes (future development)

6. Outlet Control: Automatic _____ Manual ☒
Operative _____ yes; ☒ No.

Comments:

7. Upstream Face of Dam: Condition:

1. Good ☒ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

or Comments:

8. Downstream Face of Dam:

Condition: 1. Good ✓ 2. Minor Repairs _____
 3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

9. Emergency Spillway: NONE

Condition: 1. Good _____ 2. Minor Repairs _____
 3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

10. Water Level at time of inspection: 5 ft. above _____ below ✓
 top of dam ✓ principal spillway _____
 other _____

11. Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment NO
 Animal Burrows and Washouts NO
 Damage to slopes or top of dam NO
 Cracked or Damaged Masonry NO
 Evidence of Seepage NO
 Evidence of Piping NO
 Erosion NO
 Leaks NO
 Trash and/or debris impeding flow NO
 Clogged or blocked spillway NO
 Other NO

12. Remarks & Recommendations: (Fully Explain)

THIS DAM IS IN VERY GOOD CONDITION AND WELL
MAINTAINED BY CITY OF WORCESTER WATER
DEPT.

*This appears to be a pump house. What is it
doing in our listing? Confirm!!!*

13. Overall Condition:

1. Safe ✓
2. Minor repairs needed _____
3. Conditionally safe - major repairs needed _____
4. Unsafe _____
5. Reservoir impoundment no longer exists (explain)
Recommend removal from inspection list _____

BOSTON COPY

DESCRIPTION OF DAM

DISTRICT 3
Submitted by MICHAUD MULCAHY + KANN Dam No. 3-14-134-4.1
Date MARCH 28, 1973 City/Town HOLDEN
Name of Dam DAM BELOW KENDALL RES.

1. Location: Topo Sheet No. 20C

Provide 8 $\frac{1}{2}$ " x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: _____ Year/s of subsequent repairs _____

3. Purpose of Dam: Water Supply ☒ Recreational _____
Irrigation _____ Other _____

4. Drainage Area: 2.5 sq. mi. _____ acres

5. Normal Ponding Area: 175 \pm acres; Ave. depth _____

Impoundments: _____ gals.; _____ acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir

GATE HOUSE i.e. summer homes, etc. _____

7. Dimensions of Dam: Length 180' \pm Max. Height 9'

Slopes: Upstream Face 2:1

Downstream Face 1:1

Width across top 28'

8. Classification of Dam by Material:

Earth ☒ Conc. Masonry ☒ Stone Masonry _____

Timber _____ Rockfill ☒ Other _____

9. A. Description of present land usage downstream of dam:

80 % rural; 20 % urban.

B. Is there a storage area or flood plain downstream of dam which could accomodate the impoundment in the event of a complete dam failure? yes ☒ no _____

DAM NO. 3-14-134-4.1

10. Risk to life and property in event of complete failure.

No. of people NONE.

No. of homes NONE.

No. of Businesses NONE.

No. of industries NONE. Type _____

No. of utilities NONE. Type _____

Railroads NONE.

Other dams 3-14-134-3.1, 03, 02, 01

Other NONE.

11. Attach Sketch of dam to this form showing section and plan on 8½" x 11" sheet.

12. HOW TO LOCATE

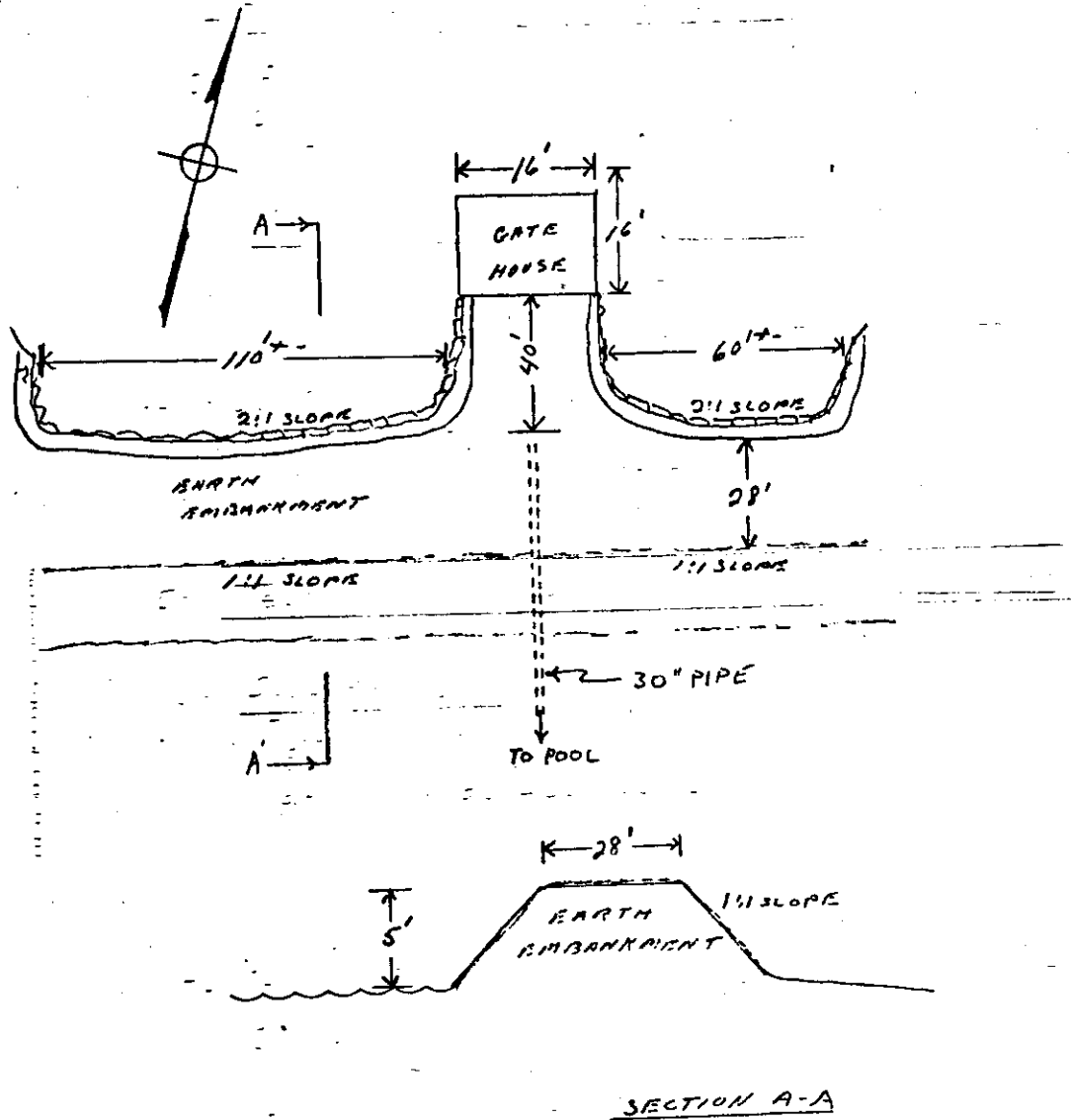
FROM 122A TAKE RTE #31 W'LY TAKE LT. ON
PAVED RD. JUST BEFORE RESERVOIR TO DAM.

HOLDEN

3-14-134-04.1

DAM BELOW MENDALL RES.

3-28-73



APPENDIX C
PHOTOGRAPHS

KENDALL RESERVOIR DAM



NO. 1 UPSTREAM SLOPE OF DAM



NO. 2 DOWNSTREAM SLOPE OF DAM



NO. 3 UPSTREAM VIEW OF SPILLWAY



NO. 4 DOWNSTREAM SPILLWAY CHANNEL



**NO. 5 DETAIL OF DETERIORATION AND SPALLING OF
WALL OF SPILLWAY CHANNEL**



**NO. 6 OUTLET FOR DIVERSION CANAL FROM
PINE HILL RESERVOIR**



NO. 7 DIKE AND GATE HOUSE AT SOUTH END OF RESERVOIR



NO. 8 DISTRIBUTION POOL DOWNSTREAM OF DIKE

APPENDIX D
HYDROLOGIC AND HYDRAULIC
COMPUTATIONS

KENDALL RESERVOIR DAM

I Test Flood, 100 year storm & Storage Functions

1- Total Drainage Area - 1.89 mi²

2- Pond(s) Area: 0.267 mi²
 Swamp(s) Area: 0.000
Total Area Pond(s) & Swamp(s): 0.267 mi²

$$\% \text{Ponds \& Swamps} = \frac{0.267}{1.89} = 14.1\%$$

3- East Side - 6.1% Slope } Say Ave Slope = 6.6%
 West Side - 7.2% Slope

4- Using C. of E. Curves for Peak Flow Rates & above guide values the Peak Flow Rate was estimated to be somewhat lower than "Rolling", and taken at 2000 c.f.s./mi². The dam size is "intermediate"; hazard potential is "high". Use Full PMF as test flood.

5- Test Flood Inflow = (2000)1.89 = 3780 c.f.s.

6- Pond Storage

The pond area is 0.267 sq. mi. at elev. 813.
 Based on a const. area, storage increases at 171 ac. feet per foot of depth increase.
 A report by M&E, Inc. (J 2188), lists the reservoir storage as 2430 acre feet - presumably below the spillway crest.
 Storage above the crest is 1197 ac. ft. at pond el 820

7- Storage Functions are based on $Q_{out} = Q_{in} [1 - \frac{S_{out}}{R}]$

S_{out} = Storage Vol. in Reservoir related to final Q_{out} in terms of inches of rain over the drainage area.

$$S(\text{in Inches}) = 12 D \left(\frac{.267}{1.89} \right) = 1.7 \quad D, R = 6 \text{ hr rain of } 5 \text{ in}$$

D = Storage Depth (above spillway) on reservoir, in feet

8- Storage Functions: (F_T & F_{100}); $D=0$ @ Res. El. 813.

$$F_{TF} = 3780 - 199 S = 3780 - 338 D$$

II Discharge Rating

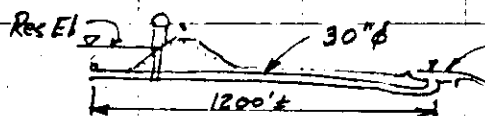
A- Spillway - [Ref. V.T. Chow - "Open Chan. Hydr." - pp 360-362]

Let $Q_s \approx 3.12 L H^{1.5} = 109.2 H^{1.5}$ w/ $L = 35'$ width
 Spillway is ungated & has no flashboards. El. = 813.

H	1	2	3	4	5	6	7	feet.
Pond El.	814	815	816	817	818	819	820	
Q_s	109	309	567	874	1221	1605	2022	cfs.

B- Low Level Outlet

[Ref.: Williams & Hazen - "Hydr. Tables" - pp 31]
 Located at southerly end of Reservoir - with
 discharge toward Holden Reservoir No. 2.



El. 795 ±

Due to Gate:

$$2 \text{ Ent.} + 2 \text{ Exit Losses} = 3 \frac{V^2}{2g} = 3 h_v$$

$$H = 1.2 \left(\frac{h_f}{1000} \right) + 3 h_v$$

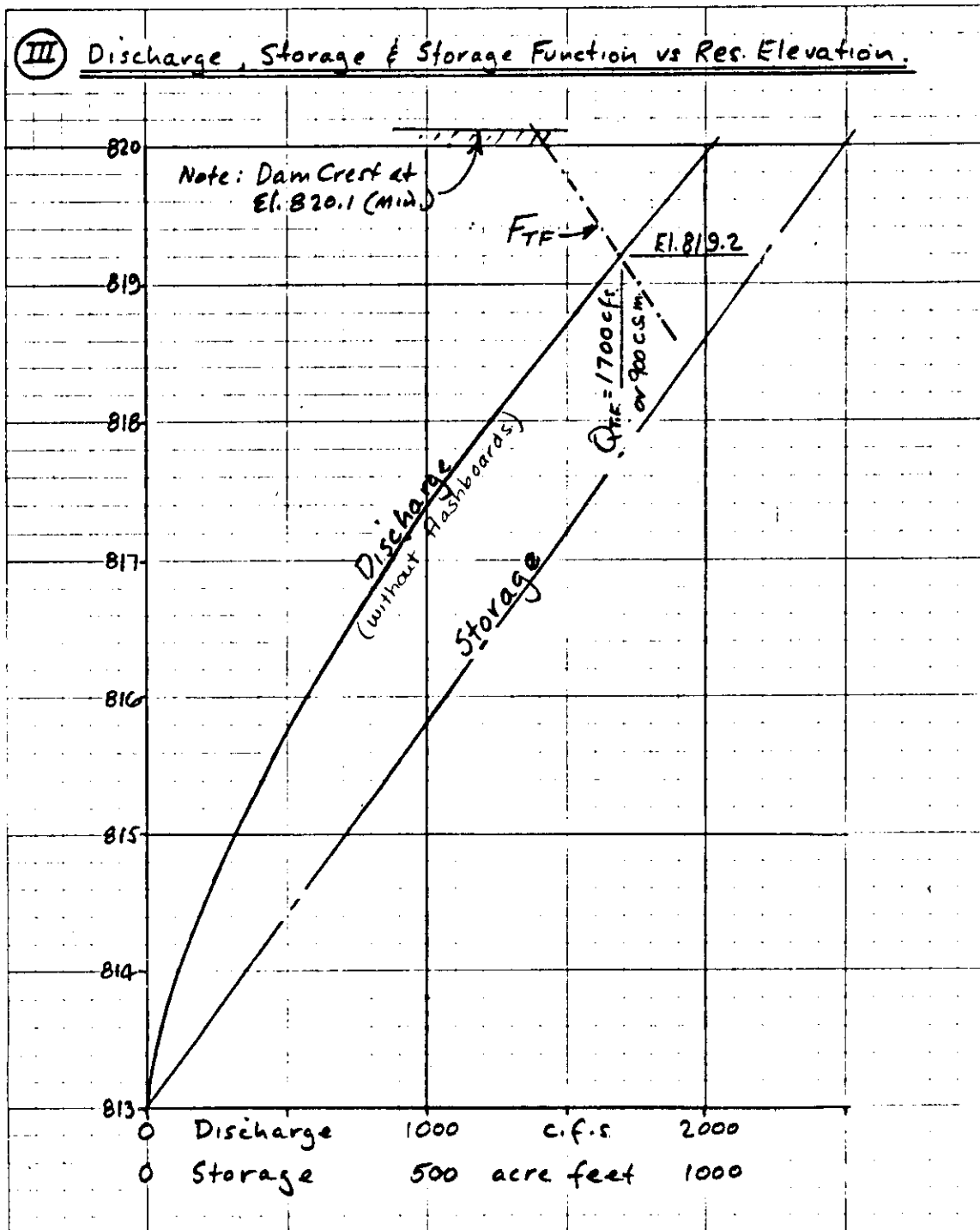
$$\text{Use } C = 110$$

Q_0	$h_f/1000$	h_v	H	Pond El.
27.85	4.28	0.5	6.6	801.6
40.23	8.4	1.04	13.2	808.2
46.42	11.0	1.39	17.4	812.4
54.1	14.7	1.89	23.3	818.3

At nominal pond elev., $Q_0 = 47 \text{ cfs} \pm$

$$\text{Time to lower reservoir } t' = \frac{(71) (43500)}{47 (3600)} = 44 \text{ hours}^*$$

* This outlet discharges to Holden Res. No 1 - If lowering
 was due to approaching storm, it would probably
 be undesirable to outlet this way.



METCALF & EDDY, ENGINEERS

Project Nat. Perisur of NonFed Dams Acct No. 5864 Page 4 of 4
 Subject Worcester Mass. Area Comptd By LEB Date 10/11/78
 Detail KENDALL RESERVOIR Ch'd. By MLL Date 11/6/78

IV Failure of Dam

Peak Failure Flow: No Overtopping - Test Flood Outflow = 1700 cfs

Pond Elevation - 819.2'

Toe Elevation - 785'

$$Y_0 = 34.2'$$

Dam Length Subject to Breaching = 332'

$$W_0 = 40\%(332') = 132.8$$

$$Q_B = 1.68 W_0 (Y_0)^{1.5} = 1.68 (132.8) (34.2)^{1.5} = 44,600 \text{ c.f.s.}$$

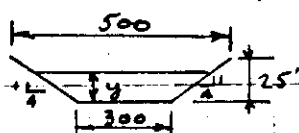
Storage Volume Released:

Storage Above Spillway 6.2(171) = 1060

Storage Below Spillway (See I-6) 2430

S = Total Storage = 3490 - Say 3,500 Ac. Ft.

Channel Hydraulics:



$$S = \frac{5}{800} = .00625, n = .06$$

$$V = \frac{1.49}{.06} R^{2/3} S^{1/2} = 1.96 R^{2/3}$$

$$A = y(300 + 4y); P = 300 + 8.25y$$

y	A	P	V	Q
2	616	316.5	3.05	1880
4	1264	333	4.77	6030
6	1944	349.5	6.15	12000
8	2656	366	7.35	19500
10	3400	382.5	8.41	28600
12	4176	399	9.38	39200
14	4984	415.5	10.3	51300

The Initial wave would be about 13 feet high at an average velocity about 10 fps.

No appreciable storage reduction could occur before the initial wave reaches Eagle Lake.

1500' Distr. is Eagle Lake, Stump P. & Swamp with a total area of 0.15 mi² ±
 Drainage of Kendall could raise the distr. ponds by 36' ±, if confined

Time to Drain:

$$\frac{43560 (3500)}{3600 (\frac{1}{2}) (44600)} = 1.9 \text{ Hours, or 114 minutes}$$

APPENDIX E

INFORMATION AS CONTAINED IN
THE NATIONAL INVENTORY OF DAMS

KENDALL RESERVOIR DAM



INVENTORY OF DAMS IN THE UNITED STATES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
STATE	IDENTITY NUMBER	DIVISION	STATE	COUNTY	CONGR. DIST.	STATE	COUNTY	CONGR. DIST.	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE DAY MO YR
MA	622	NED	MA	027	02				KENDALL RESERVOIR DAM	42°0.8	71°53.4	17NOV78

(14)	(15)
POPULAR NAME	NAME OF IMPOUNDMENT

(16)	(17)	(18)	(19)	(20)
REGION	BASIN	RIVER OR STREAM	NEAREST DOWNSTREAM CITY-TOWN-VILLAGE	DIST FROM DAM (MI.)
01	05	THASNERUMSKIT BROOK	HOLDEN	0
				POPULATION
				15630

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
TYPE OF DAM	YEAR COMPLETED	PURPOSES	STRUCTURAL HEIGHT (FT.)	HYDRAULIC HEIGHT (FT.)	IMPOUNDING CAPACITIES		DIST	OWN	FED	R	PRV/FED	SCS	A	VER/DATE	
					MAXIMUM (ACRE-FT.)	NORMAL (ACRE-FT.)									
REFRPG	1911	S	39	39	3915	2700	NED	N	N		N	N		4DEC78	

(37)
REMARKS

(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)
D/S HAS	SPILLWAY	MAXIMUM DISCHARGE (FT.)	VOLUME OF DAM (CY)	POWER CAPACITY	NAVIGATION LOCKS	NO	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)
1	1120 U 35	2022	83000															

(57)	(58)	(59)
OWNER	ENGINEERING BY	CONSTRUCTION BY
CITY OF WORCESTER	UNKNOWN	UNKNOWN

(60)	(61)	(62)	(63)
DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NONE	NONE	NONE	NONE

(64)	(65)	(66)
INSPECTION BY	INSPECTION DATE DAY MO YR	AUTHORITY FOR INSPECTION
METCALF + EDDY, INC.	13SEP78	PUBLIC LAW 92-367

(67)
REMARKS